# THE

# SILURIAN SYSTEM,

FOUNDED ON

## GEOLOGICAL RESEARCHES

IN THE COUNTIES OF

SALOP, HEREFORD, RADNOR, MONTGOMERY, CAERMARTHEN,
BRECON, PEMBROKE, MONMOUTH, GLOUCESTER,
WORCESTER, AND STAFFORD;

WITH

DESCRIPTIONS OF THE COAL-FIELDS AND OVERLYING FORMATIONS.

BY

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ETC. ETC. ETC.

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TO

# THE REV. ADAM SEDGWICK, F.R.S. V.P.G.S.

WOODWARDIAN PROFESSOR, CAMBRIDGE, ETC.

*To you, my dear Sedgwick, a large portion of whose life has been devoted to the arduous study of the older British rocks, I dedicate this work.*

*Having explored with you many a tract, both at home and abroad, I beg you to accept this offering as a memorial of friendship, and of the high sense I entertain of the value of your labours.*

*Yours most sincerely,*

RODERICK IMPEY MURCHISON.

# PREFACE.

HAVING discovered that the Region formerly inhabited by the Silures, celebrated in our annals for the defence of the great Caractacus, contained a vast and regular succession of undescribed deposits of a remote age, I have named them the "Silurian System[1]".

The Introductory Chapter details the state of the subject when this inquiry commenced, the origin and progress of the work, and the objects to be attained by its completion.

The first part, embracing descriptive geology, concludes with a review of the most striking phenomena of the ancient epochs which I seek to illustrate; the second describes the fossil animals which are imbedded in the strata. The map, coloured sections, and numerous wood-cuts, mark

[1] See a notice of the ancient topography of the Silurian Region, p. xxxi.

the subdivisions of the surface and the structure of the sub-soil; while the fossil animals are figured in separate plates.

Finally, lest some of my readers should imagine, that he whose proper study is the frame-work of the earth, is indifferent to the beauties of its outline, I beg to offer a few pictorial sketches of this fine region, alike eulogized by the poet for its fertility and the valour of its people—and which the wayfaring geologist can truly say is a land of real kindness and hospitality:

> "Where from Silurian vats high sparkling wines
> Foam in transparent floods." ——
>
> —— "In ancient days
> The Roman legions and great Cæsar found
> Our fathers no mean foes, and Cressy plains
> And Agincourt, deep tinged with blood, confess
> What the Silures' vigour unwithstood
> Could do in rigid fight."

*London, November* 29, 1838.

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ERRATUM.

*For* Philip, Thomas, Esq., *read* Thomas, Philip, Esq., Ynys Angharad, Glamorganshire.

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[a] See the list of Plates of Organic Remains and description of the Coloured Sections, pp. 713 *et seq.*

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## PLATES IN WHICH THE ORGANIC REMAINS ARE FIGURED.

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Inserted at the end of Part II.

# ERRATA.

Pages vii. and 386, *et passim*, for Narbeth, *read* Narberth.
Page 25, line 29, *for* (Pl. 29. f. 33.), *read* (Pl. 29. f. 2, 3.)
Page 38, line 30, *for* (Pl. 1. f. 2.), *read* (Pl. 29. f. 3.)
Page 44, line 20, *for* underlying systems, *read* underlying formations.
Page 49, line 13, *for* (See Chapter 5.), *read* (See Chapter 6.)
Page 64, line 9, *for* (Pl. 30. fig. 13.), *read* (Pl. 30. fig. 14.)
Page 89, line 21, *for* Mr. Loomy and Mr. Miller, *read* Mr. Looney and Mr. Mellor.
Page 125 *et seq.*, *for* Abdon and Clee Barfs, *read* Abdon and Clee Burfs.
Page 151 *note*, line 6, *for* compact cone, *read* compact coal.
Page 164, line 31, *for* the two concluding Chapters, *read* the concluding Chapters.
Page 170, line 20, and page 171, line 20, *for* Brecon fans 2500, *read* Brecon fans 2860.
Page 173, line 7, and page 516, line 30, *for* Black Mountain, *read* Black Forest.
Page 177, line 10, *for* (Pl. 36. f. 21.), *read* (Pl. 36. f. 24.)
Page 180, line 7, *for* Bromsgrove, *read* Bromyard.
Pages 181 and 182, *for* Pont-ar-lleche, *read* Pont-ar-llechau.
Page 183, line 32, *for* (Pl. 37. f. 8.), *read* (Pl. 36. f. 8.)
Page 202 *note*, line 2, *for* Mr. Davies, *read* Mr. Davis.
Page 215, line 13, for *S. trapezoidalis*, f. 14., read *S. trapezoidalis*, Pl. 5. f. 14.
Page 217, line 21, for *P. oblongus*, f. 9 and 10, read *P. oblongus*, Pl. 19. f. 9 and 10.
Page 218, line 12, for *Avicula orbicularis*, Pl. 15. f. 2., read *Avicula orbicularis*, Pl. 20. f. 2 and 3.
Page 219, line 5, for *Avicula obliqua*, Pl. 19. f. 4., read *Avicula obliqua*, Pl. 20. f. 4.
Page 219, line 5, for *Orbicula granulata*, Pl. 19. f. 5., read *Orbicula granulata*, Pl. 20. f. 5.
Page 219, line 5, for *Orthis Pecten*, Pl. 20. f. 9., read *Orthis Pecten*, Pl. 21. f. 9.
Page 219, line 10, for *Tentaculites annulatus*, Pl. 19. f. 15., read *Tentaculites annulatus*, Pl. 19. f. 16.
Page 303 *note*, line 5, for *Trinucleus Caractacus*, read *Trinucleus Caractaci*.
Page 327, line 20, *for* The same at Llandrindod, *read* The same occurs at Llandrindod.
Page 340, line 32, for *Serpuloides longissima*, read *Serpulites longissimus*.
Page 350 *note*, *for* is in the equivalent, *read* is the equivalent.
Page 363, line 6, *for* Pl. 30., *read* Pl. 27.
Page 366, line 13, *after* "mines" *insert* (Pl. 34. f. 4.)
Page 370, line 4, *for* the present chapter, *read* the present and following chapter.
Page 398, line 36, *for* Castle Rock, *read* Roche Castle.
Page 473 *note*, *for* Mr. W. Barker, *read* Mr. J. Barker.
Page 493, line 17, *for* Clent and Abberley Hills, *read* Clent Hills.
Page 501, line 14, *for* old clay works, *read* old day works.
Page 504, line 13, *for* inclined from 80° to 90°, *read* inclined from 60° to 70°.
Page 510, line 14, *for* travestine, *read* travertine.
Page 522 (*heading*), *for* Detritus of Silurian Recapitulation, *read* Detritus of Siluria.—Recapitulation.
Page 582, line 3, for *Serpuloides longissimum*, read *Serpulites longissimus*.
Page 583 *note*, line 21, for *Homanolotus Herschelii*, read *Homalonotus Herschelii*.
Page 616, line 1, for *vetustis*, read *vetustatis*.
Page 619 *et seq.*, *for* Bar Beacon, *read* Barr Beacon.
Page 627, line 23, for *Bellerophon apertus*, read *Bellerophon Wenlockensis*.
Page 637, line 34, *for* Damory Hill, *read* Damory Mill.
Page 639, line 17, *for* Corton, Clunbury, *read* Corton, near Clunbury.
Page 643, line 1, *Lituites? Cornu-arietis* (*a*), ought to have been described as a fossil of the Wenlock Shale.

# DESCRIPTION OF THE MAP.

THE accompanying Map is intended to convey a clear general idea of the geological divisions of the surface of the tract illustrated, the details being explained by numerous coloured sections. It is a reduction of the Ordnance Survey, and therefore exhibits accurately the drainage and the relative positions of the towns and villages: the form of the hills is not delineated, but as many of the heights are marked by figures, and the names of the ridges are inserted in the line of their direction, it is hoped that the general features of the country will be understood.

In the selection of colours, I have represented each great system of strata under one common tone, and its sub-formations by modified tints of the same colour. The calcareous rocks of all ages appear under shades of blue or green; the formations to which they are subordinate being known by the colour which surrounds them. The rocks of igneous origin are all represented by bright red, a method which I have employed for some years[1], from having thought that masses, the varieties of which pass imperceptibly into each other, ought at once to strike upon the eye as being derived from the same source. But after all, as colours are fugitive, and details of high interest are often crowded together into small spaces, I have inserted *letters* at intervals (particularly on the sectional lines), the meaning of which is at once explained by reference to the table of superposition.

In addition to the tabular arrangement, usually employed by other authors, I have placed below the map on the right hand, a general transverse section, in which the sedimentary formations and their subdivisions are represented in the order in which they naturally overlie each other, where no volcanic rocks are present; whilst on the left, an ideal section is given of the submarine condition of these sediments before their elevation from beneath the sea, to mark the periods when volcanic action was most in play, either when giving rise to fine detritus of scoriæ and ashes, accumulated in alternating layers with sand and mud; or during the emission of those intrusive rocks, which, whether syenites, greenstones, porphyries or basalts, are all the products of fire. Many of these volcanic rocks being inseparably connected, even within small areas, and in the same ridges, their lithological distinctions can only be understood by consulting the explanations in the text; but the epochs at which they are supposed to have been erupted, are signified by different letters,—their relations to the sedimentary deposits being rendered more intelligible by reference to the plates of coloured sections (see Plates 29—37).

A small map of England and Wales has been engraved in the corner of the large map, for the double purpose of pointing out the geographical site of the Silurian Region, and of subdividing the kingdom geologically into eight sedimentary groups, each of which I conceive (in British classifi-

[1] In the Map of the Eastern Alps, Geol. Trans., vol. iii. Pl. 35., and in the coloured Ordnance Maps of the Silurian Region exhibited at various meetings of the British Association, and at the Geological Society from 1832 to 1837. I am glad to perceive that Mr. Griffiths has adopted this method in the new Geological Map of Ireland.

cation), to be entitled to be called "Systems," from their dimensions, lithological characters, and zoological contents.

In comparing, however, the rocks of our own land with those of foreign countries, it is not contended that each of these systems has a general or even an European range. The Old Red Sandstone, for example, so vast an accumulation in the British Isles, is scarcely apparent throughout a large part of the continent, while the deposits which I have termed the "New Red System," though thus arranged in England, may not satisfy some geologists of the French or German schools. The latter may contend that in their country, the "Keuper," "Muschelkalk" and "Bunter Sandstein," form a natural group (the Trias), which is separable from the underlying "Zechstein" and "Rothe-todte-liegende" by valid distinctions. In the region, however, which I describe, such distinctions do not exist. On the contrary, all the strata between the Lias and the coal measures are composed of red and green marls and sandstones, with conglomerates, both siliceous and calcareous, the lower members of which pass gradually downwards into the Carboniferous System. This subject is fully explained in the work; and I merely now allude to it, in order to show that in these tracts the natural order of this part of the series consists in the Carboniferous System being overlaid by one red system and underlaid by another. In regard to the subdivisions of the overlying red system, some foreign geologists are, I believe, of opinion that the fossils of the "Zechstein" and "Rothe-todte-liegende" agree better with those of the carboniferous epoch than with those of the overlying red sandstone, but this point is, I am led to believe, far from being satisfactorily adjusted; for although there may be a species or two of Mollusk common to the Magnesian Limestone and the Mountain or coal Limestone, the great mass of the fossils of the two formations are distinct. That the fishes are distinct has been clearly proved by M. Agassiz, while no researches have yet brought to light a Saurian in the coal measures, though several species of this class occur in the Magnesian Limestone. This last-mentioned zoological distinction is so strong that it seems to me to outweigh in value any conclusions drawn from the Mollusca. Again, if an identity between one or two species of Mollusca is to be made the groundwork for grouping together the Magnesian and Mountain Limestone, we may for the same reason connect the Magnesian Limestone with the overlying group (the Trias of the Germans), because the lily encrinite of the Muschelkalk, and, if I mistake not, a chambered shell of that rock have been discovered in the Magnesian Limestone.

As, however, the Silurian region exhibits passages from every formation into the overlying and underlying strata, so must of necessity the lines of demarcation be more or less arbitrarily drawn; and all that I seek to prove is, that the classification now put forth is best suited to this part of England, however little it may be adapted to other countries. In short, whatever may be the arrangement on the continent, British geologists have reason to claim for themselves the privilege of defining the upper and lower limits of the great Carboniferous System, seeing that it is more copious in our country than in any other part of Europe.

But to return to my own map. An effort has been made to separate the New Red Sandstone into three distinct bands. For the first time in English geology, the "Keuper Sandstone" is shown to lie in the upper red or saliferous marl[1], whilst beneath it is the ordinary New Red Sandstone which overlies the "Lower New Red Sandstone," the two last-mentioned deposits being usually separated by a calcareous conglomerate representing the Magnesian Limestone.[2]

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[1] A memoir on the Keuper Sandstone of Worcestershire and Warwickshire by Mr. H. E. Strickland and myself is in the press, and will shortly appear in the Transactions of the Geological Society.

[2] In the map I have made use of three tints of light reddish colour to distinguish, 1st, the Red Marl and its

Of the demarcations of the Old Red and Silurian Systems, it is unnecessary that I should now speak, as they are so fully treated of in the work; yet as these parts of the map are more especially illustrated by myself, I crave the indulgence of those who may follow me; begging them to consider, not merely how little the region had been previously explored, but also how much aid the geologist is deprived of in a tract where there are few mines or underground operations[1]. Still I venture to hope that this map may serve as an auxiliary to the illustration of the Ordnance Maps which is proceeding under the direction of M. De la Beche, and I trust that my labours will aid him in laying down the outlines of the various groups of rock in this region; though there can be no doubt that the details may be much improved by the discoveries of himself and his assistants.

It now remains for me to express my thanks to those friends who have aided me. Professor Sedgwick determined the outline between the Silurian and Cambrian Rocks, from the Berwyn mountain northwards. (See Map.) Mr. Lonsdale defined the course of the oolite and lias of the Cotteswold Hills. Mr. H. E. Strickland traced the boundary between the lias and red marl, as well as the line of the Keuper Sandstone throughout a large part of Worcestershire. The Rev. T. Egerton assisted me in laying down the boundary of the lias of North Salop. Mr. F. Downing enabled me to trace the boundary of the 10 yard coal-field of Dudley; Mr. Prestwich's map of the coal-field of Coal Brook Dale has been highly serviceable, as well as that of the coal-basin of the forest of Dean and adjacent country, by Mr. Maclauchlan; Sir Philip de Grey Egerton indicated the boundary of a small coal tract in North Staffordshire, and Mr. Bowman determined the outline of the Denbighshire coal-field. In the other coal-fields I have chiefly depended upon my own observations. I must further state, that after my map was engraved, an important improvement in the outline of the Carboniferous Limestone on the western flank of the south Welch coal-basin was kindly inserted by Mr. W. E. Logan, (see the transverse faults east of Llandovery and Llandeilo,) who with great perseverance and ability had, unknown to me, laid down upon the Ordnance Map many details and remarkable dislocations of the Glamorganshire basin, the northern, eastern, and western boundaries of which are all that I allude to[2].

I have to thank Colonel Colby, Lieut.-Colonel Mudge, and Major Robe employed on the Trigonometrical Survey, for their ready compliance with my wishes, in furnishing me with outlines of tracts, the sheets of which were not published when I commenced my researches, and I am also much obliged to Mr. Maclauchlan and Mr. Budgen, Ordnance Surveyors; to the former for much geological, the latter for some local valuable topographical data. The reduction, engraving

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Sandstone or the Keuper; 2nd, the Red Sandstone or Bunter Sandstein; and, 3rd, the Lower New Red or Rothe-todte-liegende, and wherever the two last-mentioned formations are known to be separated by the calcareous conglomerate or equivalent of the Magnesian Limestone, its course is indicated by a green stripe. In a note, p. 66, printed before I decided upon the extent to which the subdivision of colours could be applied to the map, it is stated that two tints of red only are employed in illustrating the New Red System.

[1] Although no one had pointed out the subdivisions of the older rocks near Ludlow, I am bound to state that Messrs. R. and W. Wright of the Ordnance Survey, have laid down very correctly the general outline of the Ludlow promontory in a map presented to the Geological Society.

[2] By reference to p. 165, printed a year-and-a-half before I became acquainted with the observations of Mr. Logan, it will be perceived that I had noticed the great transverse dislocations near the Caermarthen Fans in my earliest visits to South Wales 1832-3. I had not, however, laid them down with that precision which marks the field work of Mr. Logan.

and writing, as well as the colouring of the map and sections, (after models furnished by myself), are the work of that able and accurate, practical geographer, Mr. Gardner.

Lastly, I must declare, that to whatever extent my observations may have changed its outlines, the map of Mr. Greenough is the foundation on which I have worked; and no circumstance will more gratify me than his approval of my labours, or to find that any efforts of mine may enable him to improve the new edition of his valuable map of England and Wales.

# NOTICE OF THE ANCIENT TOPOGRAPHY OF THE SILURIAN REGION.

WE are assured by Tacitus, that the Silures were the most powerful and warlike nation of South Britain, impatient of domination, and of great valour. Such was their confidence in their Chief Caradoc (Caractacus), and so exasperated were they by the vow of the Emperor Claudius to exterminate their race, that they carried on a stubborn war, not only under their great leader, but long after his capture; defeating the legion under Manlius Valens, and wearying out Ostorius, who died exhausted with efforts to subdue them. Veranius attacked them in vain, and they were not finally conquered till the reign of Vespasian, by Julius Frontinus.

We have no precise definition of the geographical limits of the Silurian kingdom, though Cluverius and Camden state, in general terms, that it embraced the greater part of South Wales, including Herefordshire, Radnorshire, Brecknockshire, and Monmouthshire: it constituted, therefore, a large portion of the country described. Judging from the natural features of this region, I venture to believe, that the historian Hume has not erred in supposing that it extended to the banks of the Severn[1], which noble river, in some places, with the ranges of the Abberley and Malvern Hills in others, are the only natural boundaries, on the north and east suited to a powerful race who inhabited all the adjacent territory on the west. If Siluria was thus bounded, the north-western part of Worcestershire and the southern half of Shropshire were also included in it. Other geographical considerations confirm this supposition; for as we know that the Teme flowed through the Silurian territory, the passes and hills around Ludlow must have been within it; and no one who has ever placed his foot upon Mocktree Forest, or the Wenlock Edge, will believe that an enterprizing race would remain contented with the possession of one end of a chain without a flank defence, while the other offered them a strong natural boundary in the gorge of the Severn.

Again, it cannot be doubted, that the striking ridge of Caer Caradoc[2], which ranges through the centre of South Shropshire, derived its name from some of the numerous exploits of the great British chief, whose name has been thus preserved for ages, though all the surrounding tract has so long since passed from the Celtic race.

Although, however, this hill bears the name of Caractacus, it is clear that his *last* great battle was not fought on it, since Tacitus describes a rapid and deep river (*vado incerto*), over which the Roman soldiers forded to storm the opposite heights; and there is no stream larger than a feeble rivulet near Caer Caradoc. If the battle was fought on the northern banks of the Teme, as is pretty generally supposed, it may have commenced at Holloway Rocks, about two miles below Knighton, where the Ludlow formation presents a stony and rugged line of escarpment on the left bank of the Teme, which completely recalls the graphic language of Tacitus, while the river answers well to his "vado incerto," through which the legion passed. This spot agrees also with the description of the historian, in being contiguous to a British camp called the "Gaer" or "Caer" in which Caractacus probably made his great stand, and from whence, when dislodged, he retreated into the fastnesses on the north and west, Clun Forest, Stow Hill, &c. (See Map, Camden's Britannia, vol. ii. p. 404.)

Some antiquaries have supposed that the last battle of Caractacus was fought on Coxwall Knoll, near Leintwardine, and lower down the Teme, but this appears to me at variance both with the words of Tacitus and the skill of Caractacus; for this knoll, as the name implies, has no rocky precipitous face (*arduis montibus*), and

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[1] History of England, vol. i. p. 1.

[2] In speaking of the Cardok, Cradock, Querdock or Caradoc, as it has been variously written by previous authorities, Dr. Gough, in his Edition of Camden, cites Pennant, who after showing that it could not have been the scite of the last battle of Caractacus, yet adds, "It is highly probable that it had been a post occupied by and named from Caractacus. It has been considered from very remote times a stronghold of his.'

moreover is so insulated and detached from the hills, that had the battle been fought upon it, the Silures must have been surrounded by the victorious Romans, and could never have escaped into their mountains. The wily chief had evidently chosen a better position for his last struggle, and had wisely secured a *safe retreat*[1].

In fact, Caractacus, though beaten, not only escaped himself from this hard-fought battle, but his people carried on the war for a long subsequent period, after their King had been sacrificed through the treachery of Queen Cartismunda, in whose hospitality he confided.

But however antiquaries may eventually settle the precise demarcation of the geographical limits between the *Silures* and their less powerful neighbours the *Ordovices, Cornavii* and *Demetæ,* geologists have already honoured me by sanctioning the term "Silurian;" because the rocks which I describe under this name, in and around the Silurian Region, occupy a definite place in the series, and fill up a wide interval in the chronology of geological science. (See Introduction, Chap. I.)

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[1] The Rev. C. H. Hartshorne, who is preparing for publication a beautifully-illustrated work on the antiquities of Shropshire, entitled "Salopia Antiqua," particularly in relation to the remains of military stations, informs me, that after personal examination of the chains of the British camps and fortresses, he has come to the conclusion, that the last battle of Caractacus was fought upon the Breidden Hills. My chief objections to this opinion are, that the Severn is there too powerful a stream to be forded by infantry, except in remarkably dry weather, and that the volcanic hills in question are so insulated (see views, pp. 290, 300), that it would have been difficult for a large number of the discomfited Britons and their king to have escaped into adjoining fastnesses when attacked by so good a soldiery as that of Rome. I speak, however, merely as an old soldier, being incompetent to enter into this learned controversy, which I leave to be settled by an appeal to that eminent scholar and antiquary the Bishop of Litchfield, who is well acquainted with the ground.

In the mean time, I anticipate much instruction from the etymological researches of Mr. Hartshorne; and I regret, that not having been aware of them until after the greater portion of my work was printed, I have not been able to profit by them. He informs me that the name of *Stiper Stones* (p. 283) has its origin in the Icelandic *steypa* (fusio metallorum), a term singularly well applied to the fused and altered rocks of the metalliferous tract. *Titterstone* he derives from the Icelandic, to shake or totter, and he has substantiated the inference by clearing away the surrounding detritus from one of the columns of basalt on the summit, which he found to be a rocking stone. *Wenlock*, anciently Wimnicas (the place of wind), Latin *Venti-locus, Venti loc, Wenti loc, Wenlock.* The *Hoar Edge* (pp. 121, 220), is the boundary edge, &c. I sincerely hope that this zealous antiquary will extend his inquiries from Shropshire southwards throughout the Silurian Region; for his "Siluria Antiqua" will, to many readers, have greater attractions than my "Siluria Antiquior."

# PART I.

## THE SILURIAN REGION.

# CHAPTER I.

## INTRODUCTION.

*Design of the work.—Previous state of geological knowledge.—Order of the older fossiliferous strata.—Interval to be filled up, between the secondary deposits previously described, and the older slaty rocks.—Origin of this inquiry, and method pursued in following it out.—General view of the oldest fossiliferous deposits.*

THE chief design of the present work is, to fill up an interval in geological history, by describing certain strata, which, although they occupy a considerable thickness in the crust of the globe, and connect the secondary deposits with the older slaty rocks, have never yet been adequately examined.

A few words will explain the previous condition of this subject.—When the materials of the earth's crust first became a subject of study, they were viewed principally with reference to their mineral characters; but the attention which was afterwards directed to the imbedded animals and plants, gradually produced a revolution in the science, and gave birth to what is now the largest and most important part of Geology. Since the period when Smith in England, and Cuvier and Brongniart in France, first identified strata by their fossils, a most rapid progress has been made in the application of this method of testing the age of rocks.

Sixteen years have now elapsed since Conybeare and Phillips, in their Outlines of the Geology of England and Wales, presented us with a connected view of the succession of the sedimentary British deposits, from the most superficial to those which support the carboniferous system; and, in the succeeding years, great and important additions have been contributed to our acquaintance with the youngest or tertiary deposits particularly by Mr. Lyell.

But this method has not been so extended as to carry the chronological succession *below* the Old Red Sandstone; partly, perhaps, from a preconceived opinion, that few organic remains were likely to be detected in these formations; partly from the belief, founded on just but inadequate observation, that the many mutations which these older rocks had undergone, must have nearly obliterated the evidences of their origin, whether consisting in a clear order of superposition, or in distinctness of zoological contents.

Though, undoubtedly, such reasons deterred many from grappling with this inquiry, it must not be supposed that the ancient strata have not been studied by enlightened observers. In Great Britain we may cite the names of MacCulloch, Greenough, and Sedgwick, as those of men prominently distinguished in throwing light upon them :—the first by long examination of the Scottish mountains and numerous writings upon them ; the second by his map of England and Wales ; the last by his exposition of the order of the rocks in the north of England, a portion of which task Professor Phillips has since followed out, by publishing a monograph of the carboniferous strata. But these authors had not the peculiar advantages which have fallen to my lot ; for in the regions which they studied, there is generally an abrupt boundary-line or break between the older and newer systems. For example, in Scotland there is no sequence of fossiliferous strata beneath and connected with the Old Red Sandstone ; neither is there such a sequence in Cumberland, Westmoreland, nor the adjacent tracts of Yorkshire, nor even in Devonshire, where some of the oldest masses exist. In fact, a perfect and unbroken series of links, connecting these older rocks with the younger deposits, does not occur in any portion of these islands which had been previously examined.

On the continent, where great attention had been bestowed upon the older and crystalline rocks, from the days of De Saussure and Werner to our own, the same belief was impressed on the minds of geologists, that the great dislocations to which these ancient rocks had been subjected, had entirely dissevered them from those fossiliferous strata with which we were well acquainted. In short, there existed no foreign work in which rocks of this age were classified according to a law, founded upon superposition and characteristic organic remains.

But to proceed to facts connected with our own country. No one was aware of the existence below the Old Red Sandstone, of a regular series of deposits, containing peculiar organic remains. For example, although it was supposed, that the limestone of Dudley was of greater antiquity than the Old Red Sandstone, no one had observed that those deposits were connected by an intermediate formation of very considerable dimensions, full of organic remains. It is this formation, now termed the "Ludlow Rocks," which seems to have most escaped attention, whilst, from its position, as will appear in the sequel, it is the key which accurately reveals to us the relations of the inferior masses to the overlying strata with which we formerly were acquainted.

Of the few memoirs which had been published in the Geological Transactions, relating to parts of the region illustrated, the earliest are by Mr. A. Aikin. That accurate observer had formed a project of describing Shropshire in detail ; but having long abandoned his intention, he no sooner heard of the progress I was making in the present work, than he placed at my disposal his original notes and drawings, illustrative of certain tracts around the Wrekin and the Caradoc. In truth, at the early period when Mr. Aikin undertook the task, it was almost hopeless to attempt to unravel

the structure of Shropshire; for that county not only contains every sedimentary formation from the lias to the slates inclusive, but is also rendered most complex by the numberless dislocations of the strata, through the agency of volcanic rocks. The only other modern writers who had touched upon the ancient rocks of this part of England, were Mr. Leonard Horner in a memoir on the "Mineralogy of the Malvern Hills," Mr. Weaver in one on the "Geology of the Tortworth District," and Mr. J. Yates in a short paper on "Parts of the central Counties." These essays which are included in the Geological Transactions, though constituting valuable additions to our knowledge at the periods of their publication, had reference to limited tracts only, in most of which anomalous and disrupted relations prevented the adoption of any general view of a succession of the strata.

In this condition of the subject, I first explored the borders of England and Wales in 1831. The order of succession seen in the ridges on the left bank of the Wye, between Hay in Herefordshire and Builth in Brecknockshire, where the Old Red Sandstone is distinctly underlaid by grey fossiliferous strata, first led me to suspect, that I had met with a district containing a good part of the evidence required to lead to a systematic study of our older formations; a surmise which was confirmed by following out these rocks upon their line of bearing to the neighbourhood of Ludlow and Wenlock, where I found them much expanded. I explained my view of the subject to the first meeting of the British Association, held at York, and afterwards to the Geological Society of London. Perceiving, however, that a subject so new and so large could not be really advanced, except through patient and repeated examination, I re-explored the same districts, in 1832, and submitted details of the new acquisitions to the Geological Society; accompanying my memoirs with a set of geologically coloured maps of the Ordnance Survey.

An effort to classify these deposits was then made; but it was not until the close of the summer of 1833, that I was enabled to publish a tolerably correct synopsis or table of the various formations in the extensive region, over which my observations had progressively extended. Seven years have since elapsed, during which my attention has been almost exclusively given to the development of this subject and its collateral branches.

During the summer in which my first observations were made, Professor Sedgwick commenced a general inquiry into the structure of North Wales, for which his previous acquaintance with the slaty and crystalline rocks of Cumberland eminently qualified him. He first endeavoured to connect the transition rocks of the age of Dudley with certain calcareous slates pointed out by Mr. Greenough in North Wales; but finding no concordance between them, he was, to use his own expression, "driven to a new base line," in other words, to work upwards from the central axis or oldest rocks of Wales. As soon as he perceived that I had observed the links which connect the Old Red Sandstone with some of the inferior masses of his region, he felt the importance of

pushing the inquiry, and by his encouragement I was materially stimulated to do so. In speaking of the labours of my friend, I may truly say, that he not only shed an entirely new light on the crystalline arrangement or slaty cleavage of the North Welsh mountains, but also overcame what to most men would have proved insurmountable difficulties, in determining the order and relations of these very ancient strata amid scenes of vast dislocation. He further made several traverses across the region in which I was employed, and, sanctioning the arrangement I had adopted, he not only gave me confidence in its accuracy, but enhanced the value of my work by enabling me to unite it with his own; and thus have our joint exertions led to a general view of the sequence of the older fossiliferous deposits.

In the mean time, some kind friends who had watched the progress of my labours, and thought they might lead to important results, requested me to prepare a separate treatise; and although I had been at first desirous of confining these views (as in the case of every memoir I had previously written) to the Transactions of the Geological Society, my objections were overcome by a very flattering requisition[1].

In obeying this call, I hope I shall, at all events, promulgate some new facts, and place before geologists the history of a system of deposits, authenticated by numerous good evidences in the shape of organic remains, by far the greater part of which have never been published in any country.

While maturing these views, I became convinced that, as this large and ancient group contained peculiar organic remains, and was marked by distinctness of physical features, lithological structure, and order of superposition, it was well entitled to be considered a separate *system*. It was not therefore enough that, in my efforts to develope them, I had termed these deposits, in their natural descending order, the "Ludlow," "Wenlock," "Caradoc," and "Llandeilo" formations; without some *collective* name, no general view could be carried out, nor their relations to the whole series of deposits established. For example, the group could not be defined "Transition Rocks," because nearly every modern author had so extended the meaning of this term, as to embrace in it all the deposits, from the carboniferous series inclusive, down to the oldest slaty rocks in which organic remains cease to be perceptible; whereas the object I had specially in view was, to point out the existence of intermediate rocks of great thickness, *essentially different both in structure and organic remains from the carboniferous strata.* In early communications to the Geological Society, adopting a provisional name, I called these rocks "fossiliferous greywacke"; but this term was deemed objectionable, there being few beds in the group which can be recognised as the "grauwacke" of German mineralogists—while there are fossiliferous

[1] Originating with the Right Honourable Frankland Lewis and his son Mr. George Lewis, this requisition was soon subscribed by many resident nobility and gentry through the very friendly exertions of Lord Clive. (See List of Subscribers.)

rocks having distinctly that mineral character, both above and below those which I describe.

A geographical term was finally adopted, derived from the Silures, whose power extended over the region where these rocks are best displayed, and the name of whose illustrious chief, Caradoc (Caractacus), has been transmitted to us in a bold range of hills, composed of one of the most important formations of the system to be described. The term was no sooner proposed than sanctioned by geologists, both at home and abroad, as involving no theory, and as simply expressing the fact, that in the "Silurian region," *a complete succession of fossiliferous strata is interpolated between the Old Red Sandstone and the oldest slaty rocks.*

M. Elie de Beaumont, for example, warmly encouraged me to use this name, and with his coadjutor M. Dufrénoy has since materially contributed to give it currency on the Continent. Soon afterwards M. Boué and M. de Verneuil announced the diffusion of "Silurian" rocks in Servia and the adjacent parts of Turkey in Europe, while our countrymen Hamilton and Strickland extended their range to the Thracian Bosphorus. More recently, M. Forchhammer of Copenhagen has visited the "Silurian region" to endeavour to recognize in it the rocks of Scandinavia; and even whilst I write, MM. D'Omalius D'Halloy and Dumont are exploring it to establish a parallel between its deposits and those of Belgium. Lastly, I may state, that M. de Boblaye has honoured me by offering to translate this work into the French language.

Shortly after I proposed the name "Silurian," one or two European tracts were, indeed, pointed out as resembling that which I had selected as a type. One of the most remarkable is on the southern frontier of the Ardennes, where three formations were recognised by Dr. Buckland and Mr. Greenough as occupying the same geological position as in England and Wales; namely, between the carboniferous deposits and the older slaty rocks.

That similar deposits exist in many parts of Europe is evident from the works of Strangways, Brongniart, Von Buch, Hisinger, Dalman, Keilhau, and other writers, as well as from the fossils found in Norway, Sweden, Russia, Poland, Germany and France; though patient comparisons must be instituted before the peculiar relations of the Silurian Rocks of those countries can be established[1].

Their spread through distant regions will be again brought under consideration, in the concluding view of the general distribution of organic remains. In the mean time it

[1] I cannot attempt to enumerate the names of all the foreign authors who have written on Transition Rocks, though many of those who treat of the Organic Remains are alluded to hereafter. See Part II. Judging from the maps of Hisinger and Keilhau, I presume that both Upper and Lower Silurian Rocks exist in several districts of Sweden and Norway. It would appear that I may have been led into an error (p. 169 *note*) in supposing that the Old Red Sandstone occurs in these regions. I hope, however, at some future day, to examine personally the older rocks of Scandinavia and Russia, and to show to what extent they agree with those of our own country.

may be stated, that such deposits unquestionably exist in North America, not only as inferred from the publications of our countrymen Bigsby and Weaver, but also from the works of several American authors who have described organic remains (Dekay, Green, &c.), as well as from the letters of Mr. Featherstonhaugh and Professor Rogers. And although I have not yet seen a sufficient number of fossils to enable me to enter into details, the identity of certain species of trilobites, common to that continent and Great Britain, sufficiently sustains the accuracy of the inference. It is, indeed, probable that the Silurian strata are distributed throughout that quarter of the globe, since Mr. Charles Darwin has recently brought home from the Falkland Islands masses of rock, charged with fossils which can with difficulty be distinguished from specimens of the Caradoc sandstone,—while the existence of other Silurian Rocks in Southern Africa has been established by the evidence of organic remains collected by Dr. Smith, and first transmitted to me by Sir John Herschel.

We have, therefore, every reason to believe, that although the complete order of the foreign deposits of this age has not yet been pointed out, a little more labour will enable us to place them in parallel with our own.

But to return to England,—soon after I issued my first prospectus, Professor Sedgwick assigned to the older and contiguous rocks of Wales the name of Cambrian; and the reason is obvious; for the strata so designated are not only conterminous with the Silurian System, but are in several parts seen to rise from beneath its lowest beds, and fairly to unite with them. These names are not, however, propounded as immutable; they are simply offered as the best means we possess of clearly defining the objects to be attained.

To show that these systems, like other large groups of strata in Great Britain, occupied their true positions in the sea cliffs, both in relation to each other, and to the younger deposits, I terminated my survey, by following them into Pembrokeshire,—proving, that after a course of one hundred and sixty miles, they preserved the same relation to each other and to the overlying deposits, as in Shropshire and Herefordshire. Professor Sedgwick will complete this portion of the task, by explaining how the two systems range to the coast of North Wales, and how they are there related to the younger formations.

In tracing them to distant parts, the reader must not expect to find the Silurian rocks preserving an uniform lithological character, or conforming precisely throughout large spaces to the prevailing mineral types of the region described. This remark applies not merely to other countries of Europe, but even to distant parts of Britain: thus, although the calcareous flags of Llandeilo with their accompanying schists are considered to form the base of the Silurian System, their place is sometimes taken, often indeed they are underlaid, by sandstones of considerable thickness. Again, besides the frequent absence of beds of limestone in the Ludlow and Wenlock formations above alluded to, those deposits do not preserve the same lithological

characters over wide tracts, their colour and composition in parts of Caermarthenshire and Pembrokeshire, and also at Tortworth, being very different from those of the same rocks in Shropshire and Herefordshire. And thus the lesson which has been already taught us by an examination of the younger deposits is repeated,—that the *zoological* contents of rocks, when coupled with their *order of superposition*, are the only safe criteria of their *age*. By such proofs we are enabled to distinguish the Silurian deposits from all others previously described, and through every lithological change we can thereby separate the system into upper and lower divisions.

Quitting the Silurian rocks, and taking an ascending prospect, I may observe, that although the stratigraphical position of the Old Red Sandstone and its general relations, both in England and Scotland, were well known, no complete account of its range, succession, and zoological contents, in Herefordshire and the adjacent counties, had yet appeared, though it there forms one of the largest of the stratified British groups[1]. Perceiving that besides this great thickness, the Old Red Sandstone had an individuality of mineral character, and peculiar organic remains, I ventured for the first time to designate it a system. This step was taken, not only to mark distinctly the vastness of the strata by which the Silurian deposits are *separated* from those of the carboniferous æra, but also to indicate at one glance, that the coal measures of our country are *included* between two great red coloured systems of rock—the New Red Sandstone above, the Old Red Sandstone below.

Had my labours terminated at this point, the Silurian Rocks, and their immediate relations to the overlying and underlying deposits, might have been long ago developed; but I felt that unless the structure of the whole region in question was made known, the map would have been imperfect, and the work would have borne an unfinished character. I therefore resolved to give sketches of all the coal fields included in the area examined, and further to explain their relations to the surrounding deposits. In adopting this resolution, however, I could scarcely estimate the additional exertions required; for, with the exception of the basins of the Forest of Dean, and of South Wales, none of these coal tracts, so important in the mineral economy of the nation, had been described.

But these subjects did not exclusively engross my attention. To render their history complete, it was necessary to examine minutely all the rocks of igneous or volcanic origin, which are interlaminated with, or penetrate the strata at so many points, as well as to follow out the lines of elevation and dislocation. Further, to arrive at clear

[1] The highest mountain in South Wales, called the "Fans" or points of Brecon, from its double summit, is 2862 *feet* above the sea, and is entirely composed of nearly horizontal beds of Old Red Sandstone. Through an error of the press, (p. 170) this mountain is stated to be 2500 feet high. The height of the Caermarthen Fans is accurately given as 2590 feet. Both these mountains are seen in the view facing p. 346, and the heights of both are correctly marked in that lithograph and on the map.

deductions, it was indispensable that all the overlying formations should be examined, and their boundaries laid down upon the map.

In searching the younger deposits I learnt, that the New Red System was separable into distinct formations, one of the uppermost being found to contain a band of sandstone with peculiar fossils. Though not previously noted, this rock most clearly represents the sandstone of the "keuper" or "marnes irrisées;" while the central masses of sandstone, both by geological position and the plants they contain, are shown to occupy the place of the "bunter sandstein" or "gres bigarré" of foreign geologists.

Finally, I ascertained, that within the area of the Silurian region there were natural sections, exposing passages throughout the whole series, and thus connecting all the formations from the oolitic to the slaty Cambrian rocks; a most remarkable fact, and one perhaps almost without parallel in any European district of like extent.

I need hardly say, that these numerous branches of the subject have caused a much longer examination than was originally contemplated and have considerably retarded the appearance of these volumes. Geologists, indeed, require no apology for the delay, as they well know that the illustrations of such a work could not have been rapidly prepared; but from those friends who have not made our science their pursuit, and yet have countenanced my efforts, a larger measure of indulgence is claimed. With the aid, however, of the map, the numerous coloured sections, and pictorial views, it is hoped that this class of readers will not encounter many serious difficulties. As owners of the soil, I hope they may derive some use, not only from the efforts I have made to indicate where coal *may* be advantageously sought for, but from those which demonstrate where it *never can be found*; while a knowledge of the true nature of the sub-strata cannot fail to be of value to the agriculturist.

In deciphering the history of these rocks, I have worked from the upper or known formations to the lower or unknown, and the reader will therefore be led through a *descending* geological series. The younger stratified deposits which flank the Silurian territory on the east and north will be first described, and then the inferior sedimentary masses; while the rocks of volcanic origin, and the effects produced by their intrusion amid the strata, will be pointed out in each district in which the order of the beds has been previously established.

After being thus carried back to remote periods, during which the order of the strata has often been deranged by great dislocations and volcanic eruptions, the reader's attention will be called to the various sorts of superficial detritus of the region, which being formed out of all the solid formations, could not be intelligibly explained without a previous account of the rocks from which it has been derived. In this branch of our subject, the reasons for pursuing a descending order of inquiry no longer existing, the historical method is adopted. Beginning, therefore, with the consideration of the earliest deposited loose materials, the student will have successively placed before him each newer accumulation of gravel or sand, whether entirely marine, or formed during

the transition from a submarine condition, into the æra when the newly-raised surface was first occupied by lakes and broad rivers. He will, in short, be conducted, step by step, from the time when large portions of our island were beneath the sea, to the consideration of the deposits which are in actual progress of formation above it; and thus he will embrace in one view the passage from the vast geological epochs into the comparatively brief period of history.

The first part of the work, including the descriptive geology of the region, will then be terminated, by a review of some striking results of the present inquiry.

The second part is exclusively devoted to Zoology, and contains the evidences on which many of the principal conclusions are founded; being a description of all the fossils of the Old Red and Silurian Rocks, prefaced by a general view of the distribution of animal life during the accumulation of those ancient strata.

Geologists will determine whether the results now offered to them are worthy of their approval. If it be acknowledged, that no sound general views of the early periods of the earth's history can be obtained, without a close investigation of the beds which connect the sedimentary deposits previously known with the oldest stratified rocks, then I may venture to hope, that the endeavour to clear up this difficult subject, will be considered a step, however small, in the foundation of the science.

We already know, that certain deposits with their organic remains, may be expected to show themselves (though sometimes under different aspects) in distant lands. Thus the tertiary and secondary strata have been identified over remote parts; while our own island is remarkable for having afforded in great measure the original types of the secondary age which directed that investigation. It appears highly probable, nay, it is even to a great extent already ascertained, that phenomena of the same kind prevail with respect to the system described in this volume; and that Siluria, with its accumulations of remote antiquity teeming with organic remains, presents a table made up of some of the earlier and hitherto undeciphered pages, which the history of the earth in other countries offers to our study.

But the Silurian, though ancient, are not, as before stated, *the most* ancient fossiliferous strata. They are in truth but the upper portion of a succession of early deposits which it may hereafter be found necessary to describe under one comprehensive name. For this purpose I venture to suggest the term "Protozoic Rocks," thereby to imply the first or lowest formations in which animals or vegetables appear.

That there is a limit in the descending scale of formations, beneath which no traces of life have been discovered, is now pretty generally recognised; and looking merely to this fact, geologists may agree to use the word "Protozoic," however they may differ in their interpretation of the phenomenon.

One class of observers believe, that life did not exist when the earliest deposits took place. They hold that the oldest crystalline strata (ancient gneiss, mica schist, &c.) were formed during a period of great heat: and the astronomer seems to strengthen

this opinion, by showing that the planet must have been in a state of total or partial fusion when it assumed its present shape. Such reasoners are led to suppose, that the earliest accumulations occurred under conditions which forbade the possibility of any vital organization; and they are further strengthened in their creed, when on examining the innermost folds of the earth's covering which have been extruded, they find in them no vestiges of life. They conclude therefore, that it was only after a long time, and when the surface had to a certain extent been cooled down by succeeding changes and the addition of fresh materials, that animals and vegetables were called into existence.

Other geologists contend, that as yet we gaze but dimly into the obscure vista of these early periods; and that even if organized beings did live when the first crystalline rocks were formed, we cannot now hope to discover evident traces of their existence, owing to the great metamorphoses which subsequent agencies have produced in these masses,—metamorphoses which may be well supposed to have obliterated all traces of primeval creation.

Without here attempting to decide this question, I would merely observe, that the term "Protozoic," as above interpreted, may be used by the maintainers of either doctrine.

In conclusion, I repeat that my chief object is to develope the upper portion of this vast series;—its lower divisions belong to the task which has fortunately fallen to Professor Sedgwick.

# CHAPTER II.

## OOLITIC SYSTEM.

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### *Inferior Oolite.—Lias.—Outliers of Lias.*

ORIGINALLY I had no intention of describing any rocks of so recent an age as the Oölite and Lias. The work was to have commenced with an account of the New Red Sandstone, as the youngest secondary deposit in the vicinity of any portion of the "Silurian System." The discovery, however, of a great outlier of Lias in the North of Shropshire and adjacent part of Cheshire, where the existence of that formation had never been even suspected, has induced me to extend the plan, and to preface an account of that large insulated mass, by a few observations on the relations and structure of the Inferior Oolite of the Cotteswold Hills, and of the Lias of the Vale of Worcester and Gloucester; more particularly with the view of showing how the latter passes down into the New Red Sandstone[1].

In general terms, the Oolitic Series may be described as a great and diversified group of limestones, sandstones, grits, and clays, ranging across our island from Dorsetshire on the south-west to Yorkshire on the north-east. The central members of this group occupy the high districts of Oxfordshire and Gloucestershire, which form the eastern limits of the annexed map. In this district Mr. Lonsdale has worked out with great assiduity the relative position of the different members of the system, rectifying an important error in their classification, and laying down their outlines to a great extent on the maps of the Ordnance Survey[2].

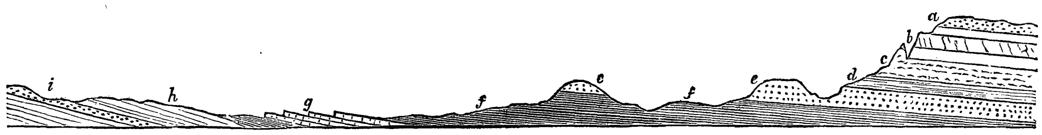
[1] Smith's Strata Identified. It was in the oolitic series of the adjacent counties, that Smith established the great principle of identifying the English strata by their imbedded organic remains. For information respecting the Oolitic Series, see Outlines of the Geology of England and Wales, by Conybeare and W. Phillips; Geology of Yorkshire, 1st Vol., by Professor Phillips. Also various Memoirs in the Transactions of the Geological Society of London, by Messrs. Buckland, De la Beche, Lonsdale, and Murchison.

[2] In pursuing his examination of the range of the Oolites, Mr. Lonsdale was the first to discover the true geological position of the Stonesfield Slates, so long known to collectors by the beauty and number of their organic remains. These Tilestones were formerly supposed to overlie the Great or Bath Oolite, but Mr. Lonsdale has shown that in the Cotteswold Range they form the bottom of that rock. Having myself examined a portion of this district in detail, I may be allowed to state my belief that no geologist could so clearly and systematically have rectified this important error of previous observers in the order of these beds, as Mr. Lonsdale; for no one had so closely studied their relations in the Bath district, whence as a type or base he extended his inquiries.

Rising from beneath the central members of the system, the Inferior Oolite and Lias appear in great force along the escarpments of the Cotteswold Hills. As the beds of these two formations have a general inclination to the east and south-east, at angles varying from 5° to 12°, it is evident that, in crossing from the Cotteswold Hills to the Severn, the strata of each group will be seen to emerge from beneath those which have been deposited over them. In this way we make our first transverse section.

The following description applies, therefore, to such strata as are found in "*descending order*," upon any straight line drawn from the escarpment of the Cotteswolds to the banks of the Severn. See coloured section Pl. 29. fig. 1. and this wood-cut.

(West.) (East.) 1.




New Red Sandstone. { h. Red and green Marl. i. Sandstone and Marl.

Lias. { d. Upper Lias. e. Marlstone. f. Lower Lias Shale. g. Limestone of the Lower Lias Shale.

Inferior Oolite. { a. "Gryphite Grits." b. Cheltenham Building-stone. c. "Pea Grit."

## *Inferior Oolite.*

The rocks composing this formation in the Cotteswold Hills are all more or less calcareous. They rise to the west, from beneath certain clays and flaglike beds (Stonesfield Slate), and occupying a thickness of about 150 feet, are divisible into three parts.

(*a.* of section.) The uppermost is a brown calcareous grit, of a very coarse aspect, owing to the number of shells it contains, among which *Gryphæa Cymbium*, *Lima proboscidea*, *Trigonia costata*, and *Pholadomya ambigua* are the most abundant. This "Gryphite grit" caps the hills, and is extracted for the use of the roads[1].

(*b.* of section.) The central division is much the thickest, and may be subdivided into three parts.

1st. Upper Ragstone, and thin-bedded Oolite.

2nd. A fine-grained, light-coloured Oolite, the Cheltenham building-stone, which varies from thirty to forty feet in thickness, and when quarried under ground is dressed with facility[2]. It is

[1] I named this stratum "Gryphite grit," from the prevalence of the "*Gryphæa Cymbium*." This name and that of Pea grit (p. 12) are local terms, applicable only to the structure of the Upper and Lower strata of the Inferior Oolite of Gloucestershire. (See Sketch of the Geology of Cheltenham, 1834. J. Murray.)

[2] In general, the Oolitic freestones, from whatever part of the system they are derived, on being exposed to the atmosphere, lose much of that moisture which they naturally possess under ground, and become much harder. The quarries of Ketton, in Northamptonshire, which are in the *Great Oolite*, yield, like those of Cheltenham, blocks of very large dimensions. These blocks are easily cut with the saw on being first extracted, but become rapidly harder on exposure to the atmosphere, and when struck with a hammer clink like a piece of metal.

undistinguishable in lithological character from the freestone of Bath (Great Oolite), although that rock is of more recent date[1].

3rd. Lower Ragstone. Very fine-grained, hard Oolite; some beds largely quarried as trough-stones. The Oolitic structure becomes coarser downwards, and passes into a rough concretionary rock at the base of the formation.

The prevailing fossils of this central division are *Clypeus sinuatus*, *Terebratula fimbria*, *T. globata*, and *T. perovalis*.

(*c*. of section.) The lowest member of the Inferior Oolite has a remarkable aspect. It is of a rusty brown colour, and is in great part made up of small flat concretions, from a quarter to half an inch in diameter, which give to the stone, on first inspection, the appearance of a Nummulite rock. It is called "Pea Grit" by the country people, and is a useful stone, when employed for gate-posts and other rough work. Coralline bodies and Pentacrinites are spread over the sandy iron-shot faces of the beds, and veins of crystallized carbonate of lime are of frequent occurrence throughout the strata.

The organic remains of the formation in these hills are very numerous, the following, collected by myself, being probably but a small portion of those which will hereafter be found.

*Fossils of the Inferior Oolite of the Cotteswold Hills*[2].

*Ammonites Brownii*. M. C. t. 263. and portions of other species of Ammonites.
———— *corrugatus*. M. C. t. 451. f. 3.
———— *elegans?* M. C. t. 94.
*Belemnites* (portion of).
*Berenicea diluviana*. Lamouroux, Expos. Méthod. t. 86. f. 12 & 14. M. C. t. 424.
*Cirrus carinatus*. M. C. t. 429.
*Clypeus sinuatus*. Parkinson, Organ. Rem. vol. iii. t. 2. f. 1.
*Corals* (of several species).
*Gervillia* ——. Species same as in Normandy.
*Gryphæa Cymbium*. Lamarck; see Deshayes, Coquilles Caractérist. des Terrains, pl. 12. f. 1 & 2.
*Isocardia concentrica*. M. C. t. 491. f. 1.
———— *rostrata*. M. C. t. 295. f. 3.
*Modiola gibbosa*. M. C. t. 211. f. 3.
*Modiola plicata*. M. C. t. 248.
*Mya calciformis*. Phill. t. 11. f. 3.
*Natica adducta*. Phill. t. 11. f. 35.
*Ostrea acuminata*. M. C. t. 135.
———— *Marshii*. M. C. t. 48.
———— *solitaria*. M. C. t. 468. f. 1.
*Pentacrinites*.
*Pholadomya ambigua*. M. C. t. 227.
———— *Fidicula*. M. C. t. 225.
———— *obtusa*. M. C. t. 197. f. 2.
*Pecten*. Species undetermined.
*Plicatula*. Species undetermined.
*Plagiostoma cardiforme*. M. C. t. 113. f. 3.
———— *giganteum*. M. C. t. 77.
———— *Parkinsonii*. M. C. t. 307.
———— *punctatum*. M. C. t. 113. f. 1 & 2.
*Terebratula emarginata*. M. C. t. 435. f. 6.
———— *fimbria*. M. C. t. 326.

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1 See note on Mr. Lonsdale's discoveries, *suprà*, p. 13.

2 The greater number of the organic remains in this list have been named and figured by Mr. J. De C. Sowerby, in his work "Mineral Conchology." The letters M. C. refer the student to that book, which forms an essential part of every Geological Library. Some of the fossils are to be found in Phillips's "Geology of Yorkshire."

*Terebratula globata*. M. C. t. 436. f. 1.
——— *media*. M. C. t. 83. f. 7.
——— *obsoleta*. M. C. t. 83.
——— *perovalis*. M. C. t. 436. f. 2 & 3.
*Trigonia costata*. M. C. t. 85.
——— *striata*. M. C. t. 237. f. 1, 2 & 3.
*Unio abductus*. Phill. pl. 11. fig. 42.

Should the observer extend his range to the south-west, he may trace similar strata, containing many of the same species of fossils, from Gloucestershire through Somersetshire, to the coast cliffs at Bridport, Dorsetshire, where he will see the beds laid bare, dipping under younger formations, and resting upon the *Lias*, as in the Cotteswold Hills. In like manner, if he follow these beds north-eastward, he will find their representatives occupying similar positions in the Oolitic escarpment of the counties of Oxford, Northampton, Rutland, and Lincolnshire, and thence extending to the high and rugged cliffs between Scarborough and Whitby in Yorkshire[1].

## *The Lias.*

The Lias, or base of the Oolitic System, forms the subsoil of the whole of the Vale of Gloucester, extending from the Cotteswold Hills to the Severn. Like the Inferior Oolite, this formation may be followed on the south-west to Lyme Regis[2] in Dorsetshire, and on the north-east to Whitby in Yorkshire. Near the latter place it is more fully developed than in any other part of the kingdom, and has there been divided by Professor Phillips into three parts. A fourfold division, however, is practicable in Gloucestershire and Worcestershire, viz.

1. *Upper Lias Shale;—(the Alum Shale of Yorkshire.)*
2. *Marlstone.*
3. *Lower Lias Shale.*
4. *Limestone of the Lower Lias Shale.*

The *Upper Lias Shale* (*d.* of section, p. 11.) consists of a bluish clay, containing occasionally nodules, or spherical concretions of dark argillaceous limestone, called in Yorkshire and elsewhere "cement stones." This subgroup ranges along the escarpment of the Cotteswold Hills, and may be seen on the sides of many of the roads where they begin to descend from the hills into the valley of the Severn. In this stratum I have observed the following organic remains.

[1] See the Geological Map of England and Wales, by Mr. Greenough. Those who desire to obtain a full knowledge of the different localities in which the same species of fossils have been found, must consult the tables in the "Geological Manual" of De la Beche (3rd edit. 1833), and the Outlines of the Geology of England and Wales, by Conybeare and Phillips, 1822.

[2] Every fossilist should visit the collection of Miss Mary Anning, at Lyme Regis, who, by her discoveries, has so materially contributed to our acquaintance with the organic remains of the *Lias*, especially in the class of those gigantic reptiles which characterize the formation.

*Ammonites annulatus.* M. C. t. 222.
———— *undulatus.* Smith, Strat. System, p. 114. Marlstone, Plate, f. 3. M. C. t. 254. f. 1 & 3.
———— *Walcottii.* M. C. t. 106.
*Arca,* or *Cucullæa?* Fragments.
*Belemnites acutus.* M. C. t. 590.
———— *penicillatus.* M. C. t. 590. f. 5 & 6.
———— *tubularis.* Phill. t. 11. f. 27.
*Gervillia.* New species.
*Inoceramus dubius.* M. C. t. 584.
*Lucina?*
*Modiola.* New species?
*Nautilus.*
*Nucula.* New species.
*Pholadomya.*
*Plicatula spinosa.* M. C. t. 245.
*Trochus bisectus.* Phill. t. 11. f. 27.

The presence of this zone of clay, which in some places must have a thickness of sixty or seventy feet, is marked by the outburst of water, either in the form of springs, or indicated by rushes and wet ground. It forms, in fact, the retentive support of all the rain-water which percolates the overlying porous strata of the Inferior Oolite, and thus gives rise to the river Chelt; to the Seven Springs, or chief sources of the Thames; to the springs which supply the Cheltenham reservoir; to those which in ancient times filled the Roman baths near Whitcomb; and to all the streamlets which, descending from the Cotteswold Hills, are tributaries of the Severn.

The *Marlstone* (*e.* of section) is made up of alternating layers of yellow and blue marly clays and sands, fox-coloured sandstone, sometimes calcareous, and beds of impure limestone.

The most prevailing fossils are—

*Avicula inæquivalvis.* M. C. t. 244. f. 2.
*Belemnites penicillatus.* M. C. t. 590. f. 5 & 6.
*Cardium truncatum.* M. C. t. 553. f. 3.
*Gryphæa gigantea.* M. C. t. 391.
*Pecten æquivalvis.* M. C. t. 136. f. 1.
*Terebratula concinna.* M. C. t. 83. f. 6.
———— *tetrahedra.* M. C. t. 83. f. 4.

Numerous ravines, by which the western sides of the Cotteswold Hills are furrowed, expose this subdivision underlying the upper shale. It is also displayed in many detached hills or outliers from the main ridge, as in Church Down, Robin Hood Hill, Battledown Hill near Cheltenham, Oxenton, and Bredon Hills.

### *Outliers of Marlstone.*

The hill of Church Down[1], which from its insulated position presents so striking an object, affords one of those examples of denudation which are frequent in the Vale of Worcester and Gloucester. The quarries upon the tabular summit are covered with a few feet of yellowish sandy loam, containing spheroidal concretions of hard calcareous grit, called "*men's heads*" by the workmen. These nodules resemble those which mark

[1] Pronounced *Chosen* by the inhabitants.

the lines of stratification in the coast cliffs near Bridport, Dorsetshire; and others which I have described as occupying nearly the same geological position in the Hebrides[1]. Beneath this sandy loam, the quarries in work, (1831,) exhibited the following beds of the Marlstone.

| | ft. | in. |
|---|---|---|
| 1. Lightish yellow micaceous sandstone full of Belemnites | 4 | 0 |
| 2. "Pot-ears." Bluish gray calcareous grit, quarried for troughs | 1 | 6 |
| 3. "Pendle." Brownish hard calc grit, jointed and fissured | 0 | 10 |
| 4. Wayboard of clay, with some fossils | 0 | 3 |
| 5. "Leathering-bed." Thick-bedded very hard micaceous marlstone, of greenish brown colour, charged with fossils, of which *Pecten æquivalvis* and *Belemnites abbreviatus* are the most abundant | 5 | 0 |
| 6. "Best double Blue." Hardest and best road-stone, weathers to a brown colour | 1 | 3 |
| 7. "Lowest Blue." A blue calcareous grit, partially discoloured by the decomposition of pyrites | 1 | 5 |

Beneath this bed the water stands upon the clay of the lower Lias, which occupies the sloping sides of the hills. A line drawn to the east, in the prolongation of the surfaces of these beds, would precisely fall upon that part of the escarpment of the Cotteswolds where the strata of the Marlstone, containing similar organic remains, occupy their regular place in the series. It is therefore evident, that the intervening valley has been hollowed out subsequently to the formation of the Lias and the Oolite; or, in other words, that there was a period when the strata of the Cotteswolds extended in continuity as far as Church Down Hill. The same explanation applies to Oxenton, Bredon, and all the other outlying masses of the Vales of Gloucester and Worcester. (See Map.)

The *Lower Lias Shale*, (*f.* of section,) or great mass of the formation, occupies the greater portion of the Vale of Gloucester and Evesham.

This Shale, resembling that of Dorset and the lower Shale of Yorkshire, is a dark-coloured calcareo-argillaceous and finely laminated deposit, containing occasionally cement stones or concretions similar to those described in the Upper Lias. Among the fossils which characterize it in the eastern part of the Vale are

*Ammonites Cheltiensis*; and 5 or 6 other Ammonites of undescribed species, some very small.
*Astacus glaber*. N. s. Phillips.
*Avicula inæquivalvis*. M. C. t. 244.
*Belemnites abbreviatus*. M. C. t. 590. f. 2, 3, & 9.
*Belemnites elongatus*. Miller, Geol. Trans. vol. ii. p. 60. pl. 7. f. 6, 7, & 8.
*Crenatula ventricosa*. M. C. t. 443.
*Cucullæa elongata*. M. C. t. 447.
*Gryphæa incurva*. Parkinson, Org. Rem. vol. iii. t. 15. f. 3.

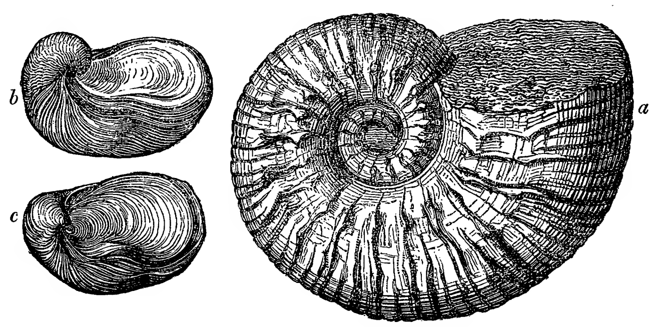
[1] Transactions of the Geological Society, New Series, vol. ii. p. 353.

*Gryphæa obliquata.* M. C. t. 112.
*Hippopodium ponderosum.* M. C. t. 250.
*Lima antiquata.* M. C. t. 214.
*Pecten.* Three undescribed species.
*Pentacrinites scalaris.* Goldfuss.
*Serpula.*
*Spirifer.*
*Turritella muricata?* M. C. t. 499.
*Unio?*

Vertebræ of the Ichthyosaurus have also been found.

The Ammonite which I have named after the town of Cheltenham *A. Cheltiensis*, is found also in the Lias of Lyme Regis in Dorset. It is represented in the following woodcut (*a.*), together with the two most characteristic bivalve shells, *Gryphæa incurva* (*b.*) and *G. obliquata* (*c.*).

2.




The cement stones frequently contain Belemnites, and *Ammonites Cheltiensis*, occasionally covered with an iridescent nacre. Many of the layers of this shale are highly charged with iron pyrites (sulphuret of iron), and when the fossil remains are coated with this mineral, it generally gives to their surface that bright metallic lustre seen upon many of the Ammonites.

*Limestone of the Lower Lias Shale*, (*g.* of section.) The right bank of the Severn in the environs of Gloucester is occupied by several plateaus of Lias, which in some points of their escarpment, as at the western part of Highnam Court, present good sections of the passage of the lowest beds of the formation into the marls of the New Red Sandstone. These consist of laminated shale, containing a few thin beds of calcareous flagstone, the whole dipping to the east and south. In following the Lower Lias thence through Gloucestershire and Worcestershire, its line of junction with the marls of the New Red Sandstone is not confined to the left bank of the Severn as marked upon previous geological maps[1]. The Lower Lias also occupies the hills between Deerhurst and Tewkesbury, and appearing on the right bank of the Severn, is quarried at Forthampton Court and at Bushley, Worcestershire; and still farther to the north it appears in the insulated hill of Longdon Heath near Upton. This is the last outlier on the right bank of the river, the formation thenceforth following

[1] For new outline west of Gloucester by Corsewood Hill, to Combe Hill on the left bank of the river, see the Map annexed to this work.

the left bank from Shothonger Common to Brockeridge Common, three miles north of Tewkesbury, whence it takes a straight course to the north-east by Boughton Hill and Pirton to Norton, four miles south-east of Worcester. In describing the structure and contents of the Lower Lias, and its junction with the marls of the New Red Sandstone along the line just mentioned, we may particularly notice a section at Combe Hill, six miles north of Gloucester, as exhibiting a perfect and conformable transition from the one system into the other. In the descending order we first perceive about 12 thin courses of dark-coloured calcareous flagstones, which are extracted for roads, paving, building, and burning to lime. These courses vary in thickness from 1 to 3 inches, and are separated from each other by stiff marl: the two lowermost bands, known locally as the "Rattler" and the "Bottom bed," are alone burnt for lime.

The surface of the flagstones is frequently covered with numerous fine and delicate species of Echini; and bones and vertebræ of Saurian animals have also been found. These beds are underlaid by sandy pyritiferous shale, graduating downwards into cream-coloured marl, succeeded by shivery, finely laminated, black shale, highly charged with iron pyrites and small crystals of selenite, and containing a few thin courses of whitish sandstone. The predominant fossils are

*Ammonites planorbis.* M. C. t. 448.[1]
*Modiola Hillana.* M. C. t. 212.
*Modiola minima.* M. C. t. 210.
*Ostrea.* Small unpublished species very abundant.

Beneath these beds of flagstone, shale, and sandstone, there is a passage, through lightish blue and grey marl, into the green and red marls, which form the upper limits of the New Red Sandstone system; the beds dipping at an angle of about 15° to the south-east. The calcareous bands are known locally under the name of "claystones[2]," and they mark the base of the Lower Lias in its course through Gloucestershire and Worcestershire. When well exposed, they are always seen to graduate downwards, through finely laminated black shale, into the same whitish sandstone observed at Combe Hill. Such relations appear in the promontory of Bushley, on the left bank of the Severn, at Corsewood Hill, two miles west of the Haw Bridge; on the sides of the high road from Tewkesbury to Ledbury; and at Forthampton Court; the small Ostrea, and *Ammonites Planorbis*, being the prevailing fossils.

An outlier called Longdon Heath, near Upton, has been during many years quarried for limestone,

[1] Remains of Saurian animals have occasionally been found in the Vale of Gloucester, both in those beds and in the Clays above, but as none of these specimens have fallen under my own observation, I cannot state to what species they belong.

[2] This "Claystone" of the Lias was formerly employed as the only road-stone; but the facilities afforded by water-carriage and the tram-roads, are now so great, that nearly all the high roads of the Vale are repaired with limestone brought from Bristol, which is termed by geologists mountain or carboniferous limestone. Being much more free from earthy matter, and more crystalline than the claystone, it forms a more durable road.

of which six beds are used, and known by the names of "Top," "Black," "Tile," "Poacher," "Peaver," and "Bottom." The Poacher is an irregular course appearing and disappearing; the "Bottom" is the best stone, and is seven inches thick. The strata on the north-west end of the hill dip east-south-east 6°, but where they crop out the inclination increases to 12° and 15°. On the higher parts of the hill the dip is north-east, and in its east-north-eastern face there are quarries twenty feet deep, where the dip is west-south-west. This outlier and the range of Lias by Bushley are, for the most part, covered with drifted superficial matter, composed of red clay, or gravel and sand, which generally conceals the subsoil in this part of Worcestershire.

At Brockeridge Common, north of Tewkesbury, the same strata are very well exposed, the workmen reckoning five principal calcareous beds, including one of *Tilestone*. These are overlaid by hard layers, and underlaid by slaty clay, which towards the base becomes sandy, and finally passes into the thin-bedded white sandstone to be described in the next chapter. The lower Lias of Brockeridge contains the characteristic fossils found at other places, viz. abundance of the small Modiolæ and Ostreæ, together with *Ammonites Planorbis, Plagiostoma giganteum,* and other fossils. The ordinary dip is about 10° south-east and east-south-east; but in one place the lowest bed rises up at an angle of 25°. As the lower Lias occupies the highest ground in the environs of Tewkesbury, it is there dignified by the title of the "hill rock" in contradistinction to the red marl, which is usually in the lower ground.

The same lithological and zoological characters are preserved along the straight ridge of the lower Lias, extending from Brockeridge Common to Boughton Hill and Pirton.

The continuation of the lower Lias from Pirton and Norton, near Worcester, into Warwickshire has been carefully traced by Mr. Strickland, jun., for many miles, and the boundaries have been laid down by him upon the Ordnance Map, including several large promontories of Lias hitherto unnoticed. He has also discovered that the New Red Sandstone has been protruded through the Lias along a line of fault near Cropthorn. It never was my intention to trace the course of the Lias into Warwickshire, and I have attempted to describe its characters in the Vale of Gloucester and Worcester, merely to point out the peculiarities of lithological structure and zoological contents, where the lower members pass downwards into the New Red Sandstone[1].

Such are the deposits which may be observed in crossing the Vale of Gloucester and Worcester from east to west. They are all rocks of sedimentary origin, and are made up of a prodigious number of beds or layers, each formation possessing an individuality of mineral character and organic remains; and as we descend in the series, we find the remains of animals differing from those which had been deposited in the beds of earlier age.

These submarine accumulations have, however, undergone great alterations since the period of their original deposit, either by denudation during their rise from beneath the sea, or by disintegration since they have been exposed to the atmosphere. They have likewise been greatly affected by disturbing agents, some remarkable proofs of

[1] The curious and important subject of the origin of the Cheltenham and other mineral waters of the Vale of the Severn, will be entered upon, as soon as we have described those rocks in which they take their rise.

which occur in the Cotteswold Hills, where the strata of Inferior Oolite dip in opposite directions, and at high angles of inclination. Detailed accounts, however, of these phenomena do not fall within the province of this work, and a correct acquaintance with them can be only obtained by long and patient research.

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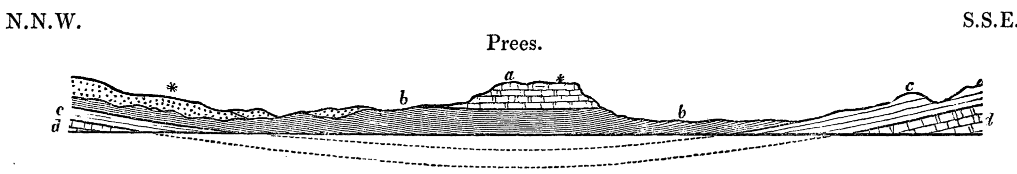
*On an Outlier of Lias in the North of Shropshire and South of Cheshire.*

Relying upon the general belief of English geologists, that the low country of North Salop and the South of Cheshire was occupied exclusively by the New Red Sandstone or detritus covering that formation, I did not, during the first three years of survey of the adjoining country, extend my researches beyond the Hawkstone and Hodnet Hills, lying about fifteen miles to the north and north-north-east of Shrewsbury. In October, 1834, I accidentally learnt that sinkings in search of coal, had been prosecuted to some extent in the district between Whitchurch and Market Drayton. On examining the district I was soon convinced that the black shale, supposed by the inhabitants to be *coal shale*, was nothing more than Lias, as was proved by an abundance of fossils; and that far from being confined to one spot, this formation, though much obscured by gravel and clay, could be detected over a considerable area. I also found that this mass of Lias was deposited in a basin, of shape more or less elliptical, from beneath which the New Red Sandstone rises to the south in the hills of Hawkstone, to the south-east at Market Drayton, to the east at Belton, to the north-east in the rising grounds extending towards Nantwich, and to the north-west in the undulating country near Whitchurch. (See Plate 29. fig. 2. and this wood-cut.)

3.




* Superficial Gravel, &c. *a.* Marlstone. *b.* Lower Lias. *c.* Saliferous Red Marl. *d.* Red Sandstone.

The western boundary is ill defined, owing to the low and featureless form of the ground and its being covered by vast accumulations of gravel, sand, and peat-bog. It is, therefore, possible that the Lias may extend in this direction to some distance; but, even assuming that it does not, and limiting the boundary by a line passing from Wem and Edstaston to Burley Dam, east of Combermere, places where the formation has

been detected, we find that this bowl has a length of about ten, and a breadth of three to four and a half miles[1]. The greater part of this district consists of Lower Lias Shale, but the overlying subdivision of the Marlstone is also apparent.

*Marlstone.*—This member of the Lias is well exposed in the hill on which the church of Prees is built, (see centre of wood-cut above, and Plate 29. fig. 2.) both in quarries and by the sides of the roads, dipping to the north-north-east at low angles. The upper beds are composed of yellowish and greenish thin-bedded sandstone, slightly micaceous, and in part calcareous; the middle, of other yellowish sandstones, some of which are more calcareous; and the lowest beds, of sandy, dark-coloured slaty marl, and shale with flattened spheroids of impure blue Lias limestone, which are undistinguishable from the well-known cement-stones of the Yorkshire coast. The fossils which I obtained are those which best characterize the Marlstone in Worcestershire and Gloucestershire, viz.

*Avicula inæquivalvis.* M. C. t. 244. f. 2. *Pecten æquivalvis.* M. C. t. 136. f. 1.
*Gryphæa gigantea.* M. C. t. 391.

together with an Ammonite which appears to be referrible to *Ammonites geometricus* (Phillips) of the Yorkshire Lias.

*Lower Lias.*—The Lower Lias consists entirely of finely laminated shale, as proved by shafts which have been sunk on Wolliston Common. In the vicinity of Burley Dam, some of the beds are so hard as to have induced Lord Combermere to quarry them for slating purposes, and others at the same locality being slightly bituminous have very much the mineral aspect of Kimmeridge Coal[2]. At Lightwood Green, the shale was found to contain nodules of ferruginous cement-stone: while at Cloverly, beneath numerous beds of dark marly shale, occurred one thin band of hard white stone with others of a blue colour. These bands have been traced by the Rev. Thomas Egerton, from Moreton Wood near Cloverly Hall, to Audlem and Burley Dam.

The natural facilities for examining the deposit are few, the surface being generally covered by superficial clay and coarse gravel, sometimes to the thickness of twenty or thirty yards, but its characters have been abundantly ascertained by borings for coal at Heathgate, Moreton Wood, Prees Wood, Calver Hall, Burley Dam, Marchamly, Cloverly,

[1] At Moreton Wood the Lias dips westerly, thus indicating, that it is there near the eastern side of the basin; whilst at Audlem and Burley Dam, along the north-eastern and northern boundary, the strata dip south-west and south, at angles varying from 5° to 7°. I am much indebted to the Rev. T. Egerton and the Rev. W. Egerton for their assistance in determining the outlines of this mass of Lias.

[2] The Shale which forms the base of the upper division of the Oolitic series, occurs extensively in the coast cliffs at Kimmeridge, in the Isle of Purbeck, and hence it has been termed Kimmeridge clay. Some of the beds are very bituminous, and being occasionally used as fuel, are called Kimmeridge coal. The mineralogical characters of this formation so closely resemble coal shale, that those unacquainted with its stratigraphical position and zoological contents, particularly in Oxfordshire and other interior parts of the kingdom, have frequently sunk into it in search of coal!! See Outlines of the Geology of England and Wales, p. 177.

and Wolliston Commons, &c. It is partially exposed between the escarpment of marl-stone at Prees, and the talus of Red Marl and New Red Sandstone of the Hawkstone Hills: there are also several outcrops of the strata between Marchamly on the south, and the rising grounds of Audlem and Burley Dam on the north. The relations of the Lower Lias to the New Red Sandstone are best seen near the eastern extremity of the Hawkstone ridge; and the water forming the series of ponds to the north of Hawkstone, is probably borne up by the marls of the New Red System.

Cloverly Hall, the seat of Mr. Dod, may be taken as a centre around which the lias shale is of the greatest thickness. On Wolliston Common, for example, in one of the attempts to find coal, after sinking two hundred and forty feet, the strata were bored to the further depth of one hundred and fifty, making a total of about four hundred feet. A little black lignite or jet was found in one instance, but nothing to justify the most remote probability of the formation containing coal.

At the mouth of one of the trial pits I collected many fossils, and with the assistance of Mr. Dod and the Rev. T. Egerton, the following list has been completed:

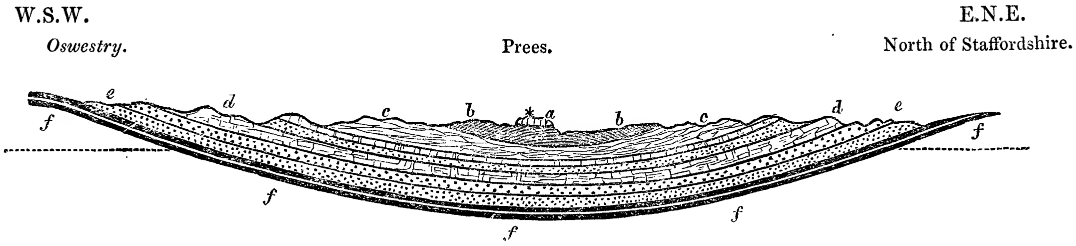
*Ammonites Bucklandi*. M. C. t. 130.
——— *communis*. M. C. t. 107.
——— *Conybeari*. M. C. t. 131.
——— *planicosta*. M. C. t. 406. f. 5 & 7.
——— *planorbis*. M. C. t. 448.
——— resembling *planicosta* (small).
——— New species (large and spinose).
——— A beautiful small species resembling one published in Zieten's Ammonites of the Wirtemberg Lias, &c.
*Astarte elegans*. M. C. t. 137. f. 3.
——— Small variety.
*Belemnites subclavatus*. Voltz sur les Bélemnites, pl. 1. fig. 11. p. 38.
——— portions of another species.
*Cidaris*. This is the first example I have met with in the Lias of any part of the *body* of Echinodermata, although many spines belonging to this family have been found in the Lias of Gloucestershire, and at Lyme Regis.
*Gryphæa incurva*. (See wood-cut, p. 19. f. 2.)
——— *Maccullochii*. M. C. pl. 547. f. 1.
*Modiola minima*. M. C. t. 210. f. 5—7.
*Pecten*. An unpublished species, occurring also in the Brora Lower Shale; see memoir Geol. Trans., vol. 2. p. 320.
*Pentacrinites scalaris* (Goldfuss).
*Plagiostoma giganteum*. M. C. t. 77.
——— *pectinoides*. M. C. t. 114. f. 4.
*Pullastra*. Unpublished; also found at Brora. Geol. Trans., vol. 2. p. 320.
*Rostellaria*.
*Spirifer Walcotti?* M. C. t. 377. f. 2.
*Tellina* —— Unpublished, probably 2 species (see memoir on Brora *ut supra*).
*Turritella*. Small unpublished species, probably same as at Banz, Germany.
*Unio Listeri*? M. C. t. 154. f. 1, 3, & 4.
Small portions of fishes or Crustacea?

This list of fossils satisfactorily establishes the precise age of the beds, for besides containing the *Ammonites Bucklandi, Conybeari*, and *planicosta*, characteristic of the Lower Lias, we have the *Ammonites Planorbis* and *Modiola minima*, both of which are distinguishing fossils of the same beds in Gloucestershire and Worcestershire. It was gratifying to find in this detached basin of North Salop, shells identical with certain

unpublished species first brought to notice by my visit to Brora, Sutherlandshire, the strata of which distant tract, containing a sort of coal, were by means of their organic remains identified with similar carbonaceous strata of the Oolitic system in the eastern moorlands of Yorkshire. Had the Lias of this Salopian tract contained coal as good as that found in the Oolitic formations of Whitby and of Brora, it might have been questionable whether in a country so distant from any deposit of the old or true coal, it would not have been worth extracting; but no trials have brought to light any portion of combustible matter, whether termed lignite or impure coal, worthy of the name of a bed[1].

To convince the resident gentry and speculators of Northern Salop who are not aware of the value of the evidence afforded by organic remains, of the hopelessness of their search after coal, I beg to repeat, that the black shale *is underlaid* by the saliferous marls of the New Red Sandstone. In addition to the instances already given I may state, that the sinkings of Sir Corbet Corbet, at Adderley, opposite Kent's Rough, and near the northern edge of the basin, proved this fact; for upon piercing the black shale to the depth of 300 feet a brine spring was reached! A similar infraposition of saliferous marls may be seen at Moss Hill farm, near Audlem. Lastly, an examination of the annexed wood-cut, and the map will show, that the basin not only rests upon marls and other strata of the New Red System, but is surrounded by them, and a reference to the general tabular view attached to this work will prove that the whole of the enormously thick system of the New Red Sandstone (as fully expanded here as in any part of England,) lies between the black shale and the true coal measures. If coal really passes beneath any portion of this country, it ought to be first sought for at points nearer to Oswestry, Chirk, Wrexham, Shrewsbury, Wellington, Newport, and Madeley in Staffordshire, in short, towards the outcrop of the coal measures which rise nearly on all sides from beneath the New Red Sandstone. Now as this tract of Cloverly and Prees, lies in the centre of the circle mentioned, it is necessarily the very spot in the whole area where the search for coal is the most hopeless, being that where the overlying deposits are thickest. (See Plate 29. fig. 23.)

W.S.W. E.N.E. 4.




*a.* Marlstone. *b.* Lower Lias. *c.* Saliferous Marl, &c. *d.* New Red Sandstone.
*e.* Calcareous Conglomerate and Lower New Red Sandstone. *f.* Coal Measures.

[1] The working of the Brora Coal, though undertaken with the greatest spirit and continued at considerable expense by the late Duke of Sutherland, has now been entirely abandoned, owing to its pyritous impure quality and consequent tendency to spontaneous combustion. (See Geol. Trans., vol. ii. p. 293.)

But if no useful practical results attend the discovery of this large mass of Lias, its detached position gives rise to interesting geological speculations. Seeing that it is sixty miles from the nearest point of the main escarpment of that formation in Worcestershire and Warwickshire, and nearly two hundred miles distant from the Lias of the north-east coast of Ireland, may we infer that the deposit was at one time continuous between these remote places? Was it connected at any period with those still more remote beds of the same age, and containing the same fossils, which are spread over the Hebrides, and appear at Brora on the north-east coast of Scotland? Or, shall we conclude that these isolated patches were originally deposited in widely distant bays, separated from each other by ridges of older rock? It is perhaps impossible to answer satisfactorily all these questions, but in a future chapter I shall endeavour to show, that in this region at all events, certain phenomena of elevation entitle us to speculate on the probable former connexion of the outlier of North Salop, with the main mass of the formation in Warwickshire and Worcestershire.

# CHAPTER III.

## NEW RED SYSTEM.

### *UPPER FORMATIONS.*

#### 1. *Saliferous Marls, &c.*—2. *Red Sandstone and Quartzose Conglomerate.*

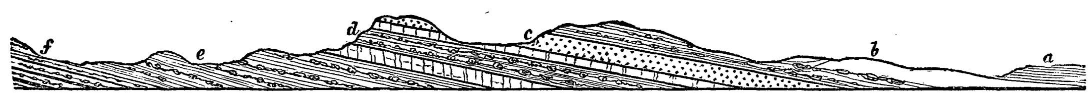
IN the preceding chapter it has been shown, that the Lias is succeeded by beds of green and red marl, constituting the upper portion of the great series of strata, called in the annexed stratigraphical table the New Red System. In this system are included all those deposits of marl, sandstone, and limestone, which lie between the Lias and the carboniferous rocks, and which from their great development in certain parts of the island, are capable of being divided into formations, by differences in lithological and fossiliferous characters. In the South-west of England, Messrs. Buckland and Conybeare[1] have described them as consisting of upper marls, central sandstones, and a lower deposit of conglomerate, composed of fragments of carboniferous limestone cemented by a calcareous paste containing magnesia. The last-mentioned rock, called by them the Dolomitic conglomerate, is the equivalent of the magnesian limestone of Durham and Yorkshire, and lies *unconformably* upon the coal measures. In the North-east of En-

[1] With regret I observe, that in reference to this system, my distinguished friends Messrs. Buckland and Conybeare have recently abandoned (it is to be hoped for a short time only) the simple English name of New Red Sandstone, adopting the Greek derivative "Pœcilitic" or "Poikilitic," which being translated means variegated or spotted, the "Bunter" of the Germans, or "Irisé" of the French. There are strong reasons why this *hard* word should not be received in our geological tables. 1st. There are great masses of the New Red Sandstone which are not spotted or variegated. 2ndly. There are vast tracts of England, Scotland, and Ireland, in which the Old Red Sandstone is quite as much spotted as the New. Now, as the great object of nomenclature and classification is to simplify, I cannot perceive why in the very region, of all others in Europe, where the distinctions which have led to a great stratigraphical separation between the *New* and *Old* Red Sandstones are best displayed, a name should now be borrowed from the French, which with equal fitness may be applied to either of these systems, since it expresses nothing more than a lithological feature common to them both. I therefore earnestly hope that the long-established and well-understood names of New and Old Red Sandstone, the one above, the other below the coal measures, may be adhered to by all British geologists. In France the nomenclature of Brongniart might well be received, since in that country there is no great system representing the Old Red Sandstone of the British Islands, though we know that it is largely developed in Norway, and, according to Mr. Lyell, in Silesia and Bohemia. (See Principles of Geology, vol. iv. p. 313. Ed. 4.)

gland, however, where the lower members of this system are much more fully developed, the subsequent researches of Professor Sedgwick have thrown a new light on these relations, proving that a great thickness of sandstone is there interpolated between the magnesian limestone and the carboniferous strata; and further establishing the important fact, that the coal measures of that region sometimes pass conformably into the lower New Red Sandstone[1]. I now proceed to show, that in the central counties, where its structure was once deemed "obscure to the most acute geologists[2]," this system may also be subdivided into formations, representing those of the North of England; an acquaintance with which, will be found of great practical importance, in the neighbourhood of the underlying coal fields. In the descending order these formations are—

1. *Saliferous Marls, &c.*
2. *Red Sandstone and quartzose Conglomerate.*
3. *Calcareous Conglomerate = Magnesian Limestone.*
4. *Lower Red Sandstone.*

5.




*a.* Lower Lias. *b.* Saliferous Marls, &c. *c.* Red Sandstone and Quartzose Conglomerate.
*d.* Calcareous Conglomerate. *e.* Lower New Red Sandstone. *f.* Upper Coal Measures.

Before describing these deposits, it is desirable to cast a glance over the map, and consider their geographical position as a whole. To the south-west of Gloucester they occupy a mere band, which after many contractions and expansions between Newent, the Malvern Hills and the Severn, finally spreads out in the plains of Worcestershire. Thence the Lias and Oolite rapidly receding in a north-easterly direction, the area of the New Red Sandstone is greatly enlarged; and finally where the Silurian and Cambrian rocks terminate abruptly near Shrewsbury, the Red Sandstone wrapping round their edges, is extended over a large region, the greatest width of which, from the coal-field of Chirk and Oswestry on the west, to the Lias of Leicestershire on the east, is not less than seventy-five miles. The following observations apply to the western portion of this area, and to some of those central districts where the coal-measures and older rocks protrude through the younger deposits.

[1] Professor Sedgwick, Geol. Trans., vol. iii., thus identified this Lower New Red Sandstone with the "Rodte-todte-liegende" of German geologists; see account of this rock, in the next Chapter.

[2] Buckland and Conybeare, Geol. Trans., vol. i. p. 299. New Series. The passage alluded to, is,—"The Newer Red Sandstone exhibiting throughout its whole course an identity of character and composition, is absolutely continuous from the points in this district (Bristol and Tortworth) where it rests unconformably on the coal measures, to the plains of Salop, where its relations to the coal measures have appeared obscure to the most acute geologists." (1825.)

### 1. *Saliferous Marls and Sandstone.*

*Foreign Synonyms.*—"Keuper" of the Germans, "Marnes irisées" of the French.

(*h*. of coloured section, Plate 29. fig. 1. See also *h* of woodcut 1. p. 14. *c*. of woodcuts 3 and 4. pp. 22 and 26, and *b*. of woodcut 5. p. 28.)

The whole of the New Red System, as seen in the narrow tract near Newnham and Flaxley, in Gloucestershire, is exhibited only in the form of red and green marls, which, on the east, pass upwards into Lias, and on the west repose unconformably upon the Old Red Sandstone and Silurian Rocks. At Tibberton, five miles west of Gloucester, they include courses of hardish sandy marlstone, of a light green colour, the uppermost of which is nearly as white as chalk, and sometimes of a slightly brecciated structure. No hard stone occurs in this formation between Gloucester and Newent. As, however, we proceed northwards, the Burg Hill quarries, situated near the village of Stainton, afford an exception, and contain a sandy marlstone of lightish green and flesh colours, in some beds almost a grass-green, passing into calcareous, slightly micaceous grit. From the neighbourhood of Gloucester to the north of Upton, the Severn flows through soft Red Marl, exhibiting on its banks (as at the Mythe, north of Tewkesbury, and near Upton) vertical sections of red and green beds, with spots of each colour. Here the marls are of great thickness, and extend westward, almost to the foot of the Malvern Hills, from which they are separated by only thin zones of sandstone and occasional conglomerates. The junction line of the upper beds with the Lias, ranging from Gloucester to the north-east of Worcester, has been already described. The western boundary of the formation in Worcestershire cannot be very accurately defined, in consequence of the gravel which obscures so much of this low country; but, in general terms, it may be stated that the marls reach within a short distance of the Malvern and Abberley Hills. Subordinate to these marls, and not far removed from their junction with the Lias, are beds of whitish sandstone, which form thin courses at Combe Hill, west of Cheltenham; and at Bushley, west of Tewkesbury. At Longden they are thicker, and at Ripple on the left bank of the Severn four miles north of Tewkesbury, they swell out to twenty and thirty feet. This rock doubtless represents one of the sandstones subordinate to red and green marls which occur at Coburg, Stuttgard, and other parts of Germany, and at Luneville in France; constituting the "Keuper" formation of foreign geologists[1].

[1] To convey to my readers some notion of the nature and succession of the strata comprehended by the Germans under the term "Keuper," I herewith annex a section of that formation at Stuttgard, made by Professor Sedgwick and myself in 1828. From this and subsequent observations of my own, particularly in the neighbourhood of Nürnberg, Coburg, and Göttingen (1829), I came to the conclusion that the German formation, as established by Humboldt and Hoffmann, for the purpose of distinguishing the red marls and sandstone which rest *upon* the Muschelkalk, from those which occur *beneath* that limestone was the true equivalent of the upper division of our English New Red Sandstone. I afterwards stated this opinion to the Geological Society,

Throughout its range in Gloucestershire and Worcestershire, the red marl is never inclined at a greater angle than 15°, the average dip of the strata rarely exceeding 5° to 8°, and always to the east, or a little north or south of that point. The salt springs at Droitwich, and the numerous saline waters which rise to the surface upon the edges of the Lias, extending thence to Gloucester, have all their source in the same formation. These brine springs and the surrounding strata, were first described by

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pointing out at the same time the rocks in Germany and France which I conceived to be the equivalents of the other British secondary formations. (See Geol. Proc., vol. i. p. 353, with references to the works of Alberti, Hoffmann, Jäger, &c.)

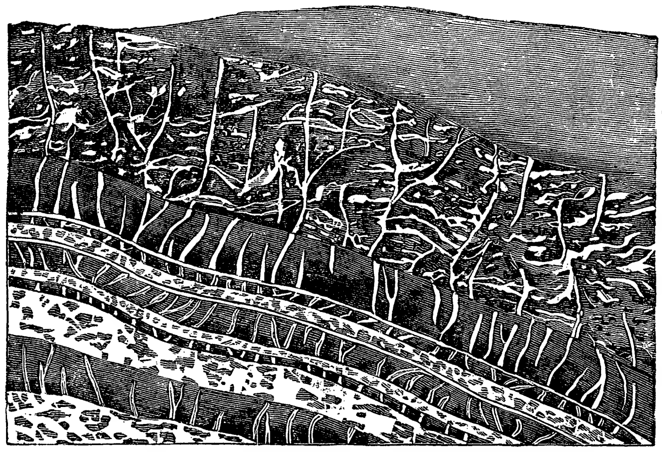
*Section of the Keuper descending from the village of Degerloch to Stuttgard.*

| | | feet. |
|---|---|---|
| *Lias.* | 1. Rusty brown and bluish marls with sandy stone bands, shells appearing in the lower part . | 10 to 12 |
| | 2. Lias limestone having a compact ferruginous exterior, and a blue interior, with many of the fossils of our Lias, and much resembling some beds in the Hebrides, as well as the lower claystones of Gloucestershire. Beds, nine inches thick, quarried for flagstones . . . . . | 9 to 10 |
| | 3. Marls and white gritty sandstone, passage into Keuper (similar to the passage described in this work) . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . | 10 to 12 |
| *Keuper.* | 4. Purple and green argillaceous marl with some hard, flaglike, slaty, micaceous sandstone . . | 60 to 80 |
| | 5. White quartzose grits, used as millstones, with green spots of marl (*Thon-gallen*), weathering reddish, but white on fracture; containing large stems of plants, some of which preserve their carbonaceous coating. (These beds are apparently in the place of the Ripple sandstone described in the text.) . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . | 16 to 20 |
| | 6. Keuper marl, like No. 4, but differing in containing subordinate thin beds of sandstone and a millstone-grit, into which the marly layers pass horizontally . . . . . . . . . . . . . . . | 80 to 100 |
| | 7. Marls with bands of compact green marlstone (like that of Burghill, Luneville and Coburg), passing into compactish limestone, with veins of sulphate of barytes and carbonate of lime. | 60 to 70 |
| | 8. Thinly laminated, shivery marls, 20 to 30 and 40 bands exposed in one section (thickness unknown). | |

The Muschelkalk limestone, which is wanting in the English New Red System, lies below the above-mentioned strata, and is seen on the banks of the river Neckar. The prevailing colours of the marls and sandstones at Stuttgard are purple and chocolate; while at Coburg the principal masses are hard calcareous grits of lively green colours, and at Nürnberg, the edifices of which city are built of Keuper, the rock is a pale red sandstone. Among the plants of the Keuper figured by Dr. Jäger and M. Adolphe Brongniart, are *Equisetum columnare*, Brong., *Calamites arenaceus*, Brong., *Calamites arenaceus minor*, Jäger, *Lycopodiolithes phlegmaroides*, Sternberg (*Lycopodites* of Brong.). See figures of other plants in this formation at Coburg in a work by Dr. Berger (Die Versteinerungen der Coburger Gegend, 1832). The shells consist of *Posidonia Keuperi*, Voltz, *P. minuta* Alberti, *Saxicava Blainvillii*, and other casts of undescribed species. In the lower beds some of the Muschelkalk fossils appear, such as, *Lima lineata*, *Avicula socialis*, Schloth., *Avicula subcostata*, *A. lineata*, and *Perna vetusta*, Goldf. Fishes occur in the formation, and they have been distinctly separated by Agassiz from those of the Lias. He remarks that "this is the most recent deposit in which the fishes of the family of Ganoids have the vertebral column prolonged into an unequal lobe, reaching to the extremity of the caudal fin." But the most remarkable remains are the Saurians, named by Dr. Jäger, *Phytosaurus cylindricodon*, and *P. cubicodon*. Some of the organic remains of this formation indicate a transition downwards from the base of the oolitic system, and one or two of the plants common to the Keuper and Lower Oolite are identical; for example, the *Equisetum columnare*, Brongn. *Oncylogonatum carbonarium*, König, Geol. Trans., vol. ii. p. 300, so abundant in the coal of the oolite at Brora, is equally common in the Keuper of Germany. In the grand duchy of Baden, where the same plant is abundantly found in schist of the Keuper formation, coal is also associated; a fact which rests on the authority of that excellent observer M. Voltz of Strasburg. (See other observations on the contents of the Keuper formation, and its separation from the Grès bigarré, p. 36, *et seq.*)

Mr. Leonard Horner[1]. Dr. Hastings has recently published an interesting account of the saliferous district around Worcester, from which we learn, that though the springs at Droitwich have been in use since the time of the Romans, it is only within these few years, that rock salt has been discovered in this neighbourhood, a fact which seems inexplicable when we recollect that many years have elapsed since it was shown by Dr. Holland[2], that masses of rock salt were the source of all the brine springs in Cheshire, the marls of which county are precisely of the same age and composition as those of Worcestershire. The account of the Droitwich springs in Nash's History of Worcester, might alone have afforded sufficient evidence of the existence of a subjacent body of rock salt, the trial sections detailed therein having passed through "rivers of salt" and alternating beds of clay, marl, and gypsum, to a "rock of salt." Notwithstanding these trials, it was only in the year 1828 that a Cheshire brine smeller, judging from various subsidences and chasms in the marl, fixed upon Stoke Prior, three miles east of Droitwich, as a spot where productive mines might be sunk. The attempt verified the correctness of his opinion and led to the discovery of rock salt. The relations of these beds of salt are well explained in the following section of the works at Stoke Prior (taken from the pamphlet of Dr. Hastings), which affords a good insight into the general structure of the red marl of this district, and shows the same association of salt with sulphate of lime, as in other parts of Europe.

6.




| | | ft. | in. |
|---|---|---|---|
| *a.* | Red and green marl | 111 | 0 |
| *b.* | Red and green marl with few distinct appearances of bedding, traversed by veins of gypsum usually vertical | 195 | 0 |
| *c.* | Red marl, containing "rock salt," nearly pure, distributed like the gypsum in the overlying mass. | 24 | 0 |
| *d.* | First layer of rock salt, red coloured and impure | | 6 |
| *e.* | Red marl with veins of salt | 3 | 6 |
| *f.* | 2nd rock salt, containing 25 per cent. of reddish marl | 10 | 0 |
| *g.* | Green marl layer | 1 | 6 |
| *h.* | Red marl with veins of salt | 12 | 6 |
| *i.* | 3rd rock salt | 6 | 6 |
| *j.* | Red marl layer with veins of salt | 2 | 6 |
| *k.* | 4th, or thick bed of rock salt, including from 7 to 20 feet of marl | 39 | 0 |
| *l.* | Red marl with veins of salt of flesh colour | 24 | 0 |
| *m.* | 5th rock salt; 30 feet thick and no bottom | 30 | 0 |
| | | feet 460 | 0 |

[1] Geol. Trans., Old Series, vol. ii. p. 94.

[2] Geol. Trans., Old Series, vol. i. p. 38.

These sinkings through a portion of the saliferous marls at Stoke Prior in Worcestershire[1] afford us some means of judging of the maximum thickness of this upper member of the New Red System, which we shall not exaggerate if we compute it at upwards of six hundred feet.

By reference to the map it will be seen that these salt mines at Stoke Prior are little more than two miles distant from the edge of the Lias at Forest Hill, near Hanbury; and as the whole body of these marls is overlaid by that formation, the section at this spot is one of the most convincing proofs in England of the exact position of the member of the New Red System, which in England is the matrix of rock salt. The perfectly analogous position of the Cheshire salt, has recently been determined by the discovery of the basin of Lias near Whitchurch and Nantwich. (See Plate 29. figs. 2 and 3, and woodcut 4. p. 25.) Numberless sections in Worcestershire, Staffordshire, or Shropshire, prove that neither rock salt nor salt springs occur in the middle or lower members of the New Red Sandstone; and hence the term "Saliferous" as applied to the *whole* system appears objectionable, since the marls in which the salt lies, constitute only the upper portion of the mass we are now considering under the general head of "the New Red System." For though in certain parts of Germany, salt appears to pervade the underlying "Bunter Sandstein," as we learn from the excellent monograph of Alberti[2], we also know that in other tracts of central Europe it abounds in tertiary strata (Wielitzka in Poland). At Cardona, in Spain, it is found in rocks of the age of our green sand; in the Austrian Alps it has been shown by Professor Sedgwick and myself to occur in limestone of the oolitic system[3]; whilst in many countries, including England, saline springs occasionally burst out from the carboniferous and older systems of rock.

I have never detected any traces of organic remains in this upper formation of the New Red System in England, though in Germany I have observed them in several localities, in the alternating masses of marl and sandstone which there constitute the Keuper. (See note, p. 30.) In a memoir communicated to the Geological Society while these pages are going through the press, Dr. Buckland has described the sandstone of Warwick, Pyle in Glamorganshire, Sutton Mallet near Bridgewater, and several localities near Taunton, as a part of the Keuper formation; resting his conclusions on the lithological character of the stone, and the discovery of an unknown species of Saurian,

[1] Owing to the undulating nature of the country, the natural sections of red and green marl near Droitwich are clearly exposed; but at Stoke Prior the surface is level, and has been extensively denuded and covered by gravel; it is therefore by shaft sections only that we there ascertain the succession of the strata. I recently visited this spot to examine the sides of a new shaft, and from the appearance of the spotted marls and gypseous beds which were exposed, I have no doubt that the section given in the woodcut, p. 31, may be depended upon.

[2] Monographie des bunten Sandsteins, Muschelkalks und Keuper. Stuttgard, 1834. This work is full of merit and accurate research, though I cannot say that the new word *Trias* of the author, appears to me a happy selection in reference to these three formations; nor can we apply it in England, seeing that one of them, the Muschelkalk, is wanting.

[3] Geol. Trans., vol. iii. p. 30; Proceedings Geol. Soc., vol. i. p. 227; and Phil. Mag., vol. viii. pp. 64 and 81. plate 2.

found some years ago in the sandstone of Warwick, and considered by Dr. Buckland to be allied to the genus *Phytosaurus,* associated with fragments of plants, which are in too mutilated a state to allow the species to be ascertained.

This view does not coincide with my conclusions respecting the English equivalents of the Keuper; for I believe that the German formation is represented by our saliferous marls, with the sandstone before described; and it will presently be shown that masses of rock much resembling that of Warwick, and apparently occupying the same stratigraphical position, must be considered to form an integral part of the underlying New Red Sandstone (Bunter Sandstein, Grès bigarré). The occurrence of a Saurian, even if the genus were established, could not prove the beds of Warwick to belong to the Keuper; for we know that in the upper secondary formations, the remains of *Hylæosaurus* have been discovered both in the Lower Green Sand and in the Wealden, though the first of these formations is of marine, and the second of freshwater or estuary origin; while with reference to the rocks now under consideration, M. Voltz has taught us, that Saurians occur in the Grès bigarré or Red Sandstone beneath the Muschelkalk, as well as in the Keuper above it.

The fossils of the overlying and underlying formations in England being of marine origin, there is little doubt that the red marl must also have been deposited beneath the sea. In Germany and in France this inference is established by the presence of marine remains in the Keuper, Muschelkalk, and Bunter Sandstein, the three upper formations of the system; the first of which, as before mentioned, represents our saliferous marls. The second or great calcareous formation has not yet been discovered in the British Isles; and the third is the equivalent of those massive central sandstones of our system treated of in the following part of this chapter. The numerous brine springs as well as masses of rock salt which are contained in the red marl, seem to offer additional proofs of the marine origin of these deposits, since Dr. Daubeny has shown, that in many of these saline sources there is an admixture of iodine, a principle which is confined to the sea and its productions. This argument is not however to be considered decisive, but only as forming a portion of cumulative evidence, which taken in conjunction with that of the remains occurring in the deposits of this age on the Continent, fortifies the conclusion that our saliferous marls are of marine origin; for it might be said that iodine and chloride of sodium have been derived in the first instance from the interior of the earth, and that the ocean may have owed its saltness to beds of rock salt, as well as that rock salt owes its origin to the evaporation of sea-water.

These considerations lead us naturally to an examination of the origin of the mineral springs so abundant in the Vales of Gloucester, Worcester, &c.

## *Mineral Springs of Gloucestershire and Worcestershire.*

The true nature and geological position of the strata through which these springs rise had not been described before the year 1833, when I made them known in a brief sketch of the geology of the environs of Cheltenham. In one of the previously published analyses, the Cotteswold Hills were assumed to be "magnesian limestone," and the blue clay through which the waters ascend, was said to cover the limestone. That this clay, the lower Lias, passes beneath the calcareous rocks, is a fact now known to every geologist (See woodcut 1. p. 14. and Pl. 29. fig. 1.); and instead of the magnesian limestone, which does not exist in this district, the stone of the adjoining hills is proved to be the *Inferior Oolite*. Again, in a recent work, the production of an able chemist, the waters are supposed to rise through sand[1]. It was therefore desirable to show distinctly, that the lowest marly and argillaceous beds of the Lias formation, are really the strata through which these waters find their way to the surface. For a long time after their first discovery at Cheltenham, it was the general belief that they had only one source; but numerous sinkings, at depths from eighty to one hundred and thirty feet, adjacent to, and at considerable distances from the old springs, have established the fact, that many strata were saturated with water, holding in solution the chloride of sodium, the sulphates of soda and magnesia, and other mineral substances.

From the analyses of these waters by several chemists, it appears that their principal constituents are the chloride of sodium or sea salt, and the sulphates of soda and magnesia; sulphate of lime, oxide of iron, and chloride of magnesium, being present in some wells only, and in much smaller quantities[2]. The analyses have also proved, that these substances vary much in their relative proportions at different sources, a circumstance which must arise from the waters changing their composition with the varied mineral structure of the strata which they traverse. Besides the ingredients just mentioned, iodine and bromine have, as already stated, been detected in several of the sources by Dr. Daubeny[3], who has endeavoured to ascertain whether these two active principles, which the French chemists had recently discovered in modern marine productions, did not also exist in mineral salt waters, issuing from strata which geologists consider to have been formed beneath the sea; and his examination has established the

[1] Thermal and Mineral Springs, by Dr. Gairdner, 1832, p. 419: an excellent work. The mistake in this case is that of confounding the superficial sandy detritus of the district, with the formation on which it rests.

[2] The waters were formerly analysed by Brande and Parkes, subsequently by Dr. Scudamore and Dr. Daubeny. Professor Daniell has examined those of Pittville, and Mr. Cooper has recently made a very elaborate analysis of those of Montpelier, with the details of which I am not acquainted. His observations, I believe, coincide with those of Dr. Daubeny, in the detection of iodine and bromine.

[3] Philosophical Transactions, May, 1830.

existence of iodine and bromine, not only in the waters of Cheltenham, but also in the greater number of the salt-springs of Great Britain.

The previous observations in this chapter have shown, that the great subterranean storehouse of the rock salt and brine springs of England, is the red marl or upper member of the New Red Sandstone[1], which is immediately subjacent to the Lias. (See Map. Pl. 29. fig. 1.) Accordingly we find that sea salt is present in still larger quantities in those wells which occur near the western edge of the formation, where the Lias forms only a thin covering above the red marls. At the new spa near Tewkesbury, the water, though very slightly saline near the surface, was found to be much more impregnated with salt as the sinking was carried downwards; and I have no doubt that similar results would follow, by deepening any of the mineral sources which are so numerous in the Vale of Gloucester, those of Walton, the bottom of Church Down Hill, &c., for instance. Even at Cheltenham, when experimental borings were made to the depth of two hundred and sixty feet below the surface, the water of the lowest stratum of marl or clay was found to be much more highly charged with the common sea salt, and to contain less of the sulphates, than the existing wells, none of which have been sunk to a greater depth than one hundred and thirty feet.

These facts can be only accounted for under the supposition, that the source of the saline ingredients of those waters is the Saliferous Red Marl or Keuper, the uppermost strata of which must, from their known inclination, lie at depths of several hundred feet below the town of Cheltenham. (See Pl. 29. fig. 1.) If this be the case, and salt water is continually flowing upon the inclined surfaces of these beds, we can readily explain why it occasionally rises to the surface; for being collected in the New Red System at higher levels than the surface of the Vale of Gloucester, it would naturally ascend to the original level by any cracks or openings which might present themselves in the overlying Lias[2].

The salt water having thus to rise through various strata of lias shale, loaded with sulphuret of iron, it is to be presumed, that during this passage certain chemical changes take place, which give to the waters their most valuable medicinal qualities. The most important process in this moist subterranean laboratory, is probably the decomposition of the sulphuret of iron, which supplies a large quantity of sulphate of the oxide of iron, an elaboration which must be highly accelerated by the structure of the incoherent and finely laminated beds, through which the pyrites is so widely disseminated. The sulphuric acid, thus generated, will necessarily react on the different bases, such as magnesia and lime, which it may meet with in the strata, and form those sulphates so pre-

[1] See the memoir of Dr. Holland, Geol. Trans., vol. i. p. 38, and that of Mr. L. Horner, vol. vi. p. 95, Old Series; also the recent work of Dr. Hastings of Worcester. (See p. 32.)

[2] The borings for mineral water at Cheltenham are, truly speaking, Artesian wells, and ought at once to explain to the inhabitants of the Vale of Gloucester, that no *pure* water can be obtained by sinking through the Lias in the vicinity of the mineral springs.

valent in the higher or pyritous beds of the Lias, the oxide of iron being at the same time more or less completely separated. By such means, it is presumed, these mineral waters, which are simply brine springs at great depth, acquire additional and valuable properties in their ascent. In suggesting this explanation, we must not, however, overlook the fact, that fresh water is perpetually falling from the atmosphere upon the surface of the Lias clay, and, more or less, percolating its uppermost strata. Many of the saline springs must therefore be affected by this cause, and the existing condition of the various wells in the Vale of Gloucester, may ultimately depend upon three causes :—

1. The supply of salt water from the marls of the New Red System, in the manner above described;
2. The chemical action produced during the filtration of the salt water as it rises through the various strata of the Lias;
3. The supply of fresh water from the atmosphere.

The chemical relations, and medicinal virtues of these waters, have been well described in other treatises, and they are only mentioned in this place to convey a clear notion of their origin, and their dependence upon the geological structure of the district.

This reasoning respecting the origin of the Gloucestershire mineral waters may be applied to all the mineral springs which rise through the Lias of the Vales of Worcester and Warwick.

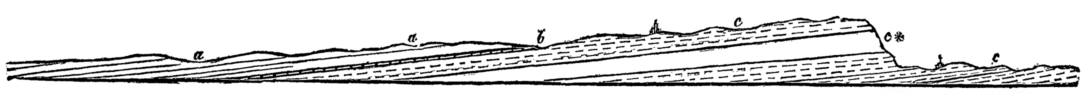
### 2. *Sandstone and Quartzose Conglomerates.*

*Foreign Synonyms.*—" Bunter Sandstein " (Ger.), " Grès bigarré " (Fr.)

The great arenaceous formation of red and variegated sandstones, constituting the Bunter Sandstein or Grès bigarré of continental geologists, is very largely developed in England, particularly in the counties of Salop, Stafford, and Worcester. In Germany, Poland, and the eastern parts of France, this formation is distinctly separated from the Keuper (our saliferous marls and sandstone), by the "*Muschelkalk*" or shelly limestone. (See note, p. 30.) In England we have not yet succeeded in recognising the equivalent of this limestone, and hence we have always wanted a clear line of separation between the formation described in the last chapter, and that which we are now to consider. When, however, we look to the vast development of the saliferous marls of our island the maximum thickness of which, including subordinate courses of sandstone, amounts to six or seven hundred feet, we should naturally be disposed to think that these comprise the whole German formation called the "Keuper," and that the true equivalent of the Muschelkalk would be found rising from beneath these red and green marls, and surmounting the sandstones and conglomerates which constitute the central or chief masses of our New Red Sandstone. Now although I cannot yet completely obviate the difficulty arising from the absence of the Muschelkalk, I may observe that

there exists a subcalcareous course in Shropshire, which appears to occupy the place of that formation. This course is exposed on the northern slopes of the Hawkstone and Clive Hills, particularly at Broughton, seven miles north of Shrewsbury, where its geological position is well defined; for it has previously been shown, that there, the Saliferous Marls or Keuper passing beneath the Lias, rise up to the south-south-east, and overlie the massive sandstones of the Hawkstone Hills. The calcareous band at Broughton dips under the saliferous marls, and distinctly rests upon the solid sandstones of Clive, Grinshill, and Hawkstone; and hence it seems to occupy precisely the position, which would be naturally assigned to the German Muschelkalk. (The position is explained in this wood-cut.)

7.




*a.* Saliferous Marls and Sandstone. *b.* Calcareous flags = Muschelkalk.
*c.* New Red Sandstone = Bunter Sandstein. *c**. White Sandstone of Grinshill included in the Red Sandstone.

The beds at Broughton are so calcareous, that they have recently been tried for lime-burning, but they proved too earthy and sandy for that purpose. They are so thin bedded as almost to constitute a flagstone, a structure never discernible in the upper or central members of the New Red System, though it will hereafter appear, that this structure occurs in some beds of the Lower New Red Sandstone, and is common to many strata of the Old Red System. The upper beds at Broughton are red, marly, sandstone flags, passing down into hard, grey, fine-grained, calcareous grit, with rough uneven surfaces, breaking into flags three or four feet square, and used as wall-stones. On exposure, these flags weather to a dirty yellowish colour, and they then very much resemble certain sandy and rubbly beds of the Muschelkalk. At the depth of a few feet they are underlaid by beds of yellowish sandstone, containing hard, round, concretions of calcareous spar, and of sub-crystalline sandy limestone. In some instances, the lime is so much disseminated through the mass, as to give to the fresh fractured surface of the stone a "chatoyant" lustre, and this appearance doubtless led to the construction of limekilns at this spot, for the rock in question is entitled to the name of bastard limestone. This rock also contains nests of calcareous spar, crystals of grey carbonate of copper, and sulphuret of iron, with occasionally small grains of black oxide of manganese diffused.

Fully aware of the importance attached to the geological position of these calcareous courses, I have twice visited the Broughton quarries, in the hope of detecting some organic remains peculiar to the Muschelkalk, but without success. Still, however, I am of opinion, that, from their stratigraphical position, these calcareous beds of Broughton may prove to be the representatives of the Muschelkalk; and I trust that the day is not

E

distant, when further excavations along the northern slopes of the Clive and Hawkstone Hills, may lead to the discovery of the zoological evidences required[1].

Near Marchamley, the eastern end of the Hawkstone Hills, a natural section is seen in the following descending order, proceeding from north to south.

1. Beds of flaglike, deep red, sandy marlstone, the uppermost passing under red and green saliferous marls, with some laminæ of greenish grey marl.
2. Thick-bedded dark red sandstone, weathering to a small cavernous or honeycomb surface, and resting on red and green marl. The strata 1. and 2. may perhaps be classed with the Keuper, or rather as the beds of passage from that formation to the great mass of New Red Sandstone. The calcareous course, however, is not so distinctly exhibited as at Broughton.
3. Hard, red sandstone, slightly calcareous and in parts cellular. On their extension to the west, these bands become of a yellowish grey colour, including veins of chalcedony, with nests of crystallized carbonate of lime, blue carbonate of copper, and black oxide of manganese disseminated both in particles and in small veins.
4. Thick masses of whitish soft sandstone without distinct lines of bedding.
5. Red sandstone appearing below the white sandstone.

These beds form a part of the Hawkstone Ridge and terrace so justly admired, but other parts of the same escarpment present different characters, and the alternations above described, give way to large continuous masses of whitish yellow, thick-bedded, earthy sandstone, forming picturesque cliffs of rounded forms, from eighty to one hundred feet high. This sandstone is composed of semi-transparent grains of quartz, very minute, apparently rounded, with a small proportion of grey cement, chiefly argillaceous, and it occasionally contains "concretions about the size of a pea, of lamellar, white and flesh-coloured sulphate of barytes[2]." It presents few clear lines of deposit, and is marked by many transverse fissures and seams of false bedding, features characteristic of all the sandy rocks of this system. The whole of the sandstone strata in the Hawkstone range, including the Clive and Harmour Hills, dip at a small angle to the north-north-west, partially surmounted, as before stated, by calcareous courses, which are supposed to represent the Muschelkalk, and passing beneath the saliferous marls which support the Lias. (Pl.29. fig. 3.) In this country, therefore, having a clear line of demarcation for the top of the system, we know that the Hawkstone rocks constitute an integral portion of the great central mass of New Red Sandstone. The surface of the sandstone near the Hermitage, is occasionally of a bright green colour, which is sometimes due to green carbonate of copper, disseminated through the rock, as seen on the sides of the park ride leading to Marchamley, though some of the specimens owe

[1] The most characteristic fossils of the Muschelkalk are *Lima striata* and *L. lineata*, Schlotheim; *Pecten lævigatus* and *P. discites*, Schloth.; *Avicula socialis* and *A. Bronnii* (*Mytilus socialis, &c.*, of Schlotheim); with the well-known and beautiful Lily encrinite, *Encrinites liliiformis*, and *Ammonites nodosus*. Some of the fossils of the Muschelkalk pass up into lower beds of the Keuper. (See note p. 30.)

[2] Aikin, MSS.

their superficial green colour to the presence of a lichen. The existence of copper ore in rocks of the same age is well known in Cheshire, both in the Peckforton Hills and in Alderley Edge. Since I last visited Shropshire, copper ore has likewise been found, and works have been opened in the New Red Sandstone near Pradoe, on the property of the Hon. Thomas Kenyon. Specimens of the rock sent to me by Colonel Wingfield, indicate the dissemination of the green carbonate, in minute quantities through the mass of sandstone. At the Peckforton Hills I examined the trial shafts of the old mine in company with the proprietor, Sir Philip Egerton, Bart., and there the ore unquestionably lies in veins and lumps, where the sandstone is dislocated and fissured. Further allusion, however, will be made to this subject and to the mineralized character of these sandstones, after the description of certain trap dykes which penetrate the New Red Sandstone of Shropshire.

Mr. A. Aikin, with his usual mineralogical precision, had remarked, more than twenty years ago, that the rocks of Hawkstone were analogous to those of Alderley Edge, in containing traces of copper ore, ferruginous oxide of cobalt, together with concretions and veins of sulphate of barytes. These minerals were at that day held to be eminently characteristic of the Old Red Sandstone, having been cited by Werner as occurring abundantly in the older Red Sandstones of Germany; but we now know that these older German Sandstones (the rothe todte liegende), are not of greater antiquity than those which form the lower part of the New Red System.

At Clive Hill, the highest part of the Broughton ridge before mentioned, and rising from beneath the calcareous courses supposed to represent the Muschelkalk, Mr. Arthur Aikin first observed "round concretions of fine sand, firmer than the surrounding matrix and much heavier, consisting of quartzy sand, cemented by sulphate of barytes, their size varying from the bulk of an apple to that of a pea. These concretions, being harder and less easily decomposable than the rest of the rock, project from its weathered surface and often become quite loose in the incoherent sand to which the rock is reduced[1]." Dark-coloured quartzose conglomerates rise from beneath these sandstones in the hills at Hodnet; and if we continue the section in direct descending order, from the escarpment at Hawkstone on the north, to the plains of Shrewsbury on the south, we pass through other and older strata of this group of the formation, composed of red sandstones, and much stiff red marl or clay. (See section, Pl. 29. fig. 3.)

The Clive and Grinshill Hills are the south-western prolongations of the Hawkstone sandstones. The cliff at Grinshill exhibits the peculiar feature of a face of sixty-five to eighty feet, of a fine-grained, whitish sandstone, included between two masses of a red colour, the overlying stratum being a rubbly, thin-bedded red rock called "Fee;" the underlying mass, a deep-coloured red sandstone, which has been bored through in search of water to the depth of upwards of two hundred and twenty feet, without affording any sensible difference in its composition. The red cap, or "Fee," is mere refuse or marly sandstone, and the red sandstone at the base of the hill is simply a soft thick-

[1] MSS. of Mr. Aikin.

bedded red stone, undistinguishable from the rock in many other parts of its range. But the included mass of light-coloured free-stone is well worthy of description, being perhaps the finest example in England of so deep a section of stone of this quality, in the New Red System[1]. Some of the beds are quite equal in value to any free-stone of the coal-measures, from which they differ in being entirely free from stains of carbonaceous matter, and here and there slightly variegated by streaks of a delicate pink hue: others have also occasionally a yellow tinge due to the decomposition of iron pyrites. The stone is for the most part rather heavier than other free-stones, in consequence, as suggested by Mr. A. Aikin, of the grains of grey sand being contained in a cement composed chiefly of heavy spar (sulphate of barytes)[2]. The beds vary in thickness from two to eleven feet, and are generally so closely fitted to each other that there is only one very thin parting of clay from the top to the bottom of this fine face of rock[3].

The subjoined section affords the details. The strata dip about 6° north-north-west, by which inclination they pass distinctly beneath the calcareous bands of Broughton.

*Section of Grinshill Stone Quarries.*

| | ft. | in. |
|---|---|---|
| Fee, pronounced "Fay," a red rubbly thin-bedded rock, with some marl. . . . . . . . . | 13 | 0 |
| Flag-rock, yellowish and light brown colour, in thin beds, the thickest being fourteen inches; used for flagging, chimney-pieces, monuments, and other interior work . . . . | 19 | 0 |
| Sand bed nine inches deep, called *Esh* . . . . . . . . . . . . . . . . . . . . . . . . . . | 0 | 9 |
| Hard Burr (compact rag) . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . | 2 | 6 |
| Coarse Freestone, rather mottled, of yellow, and reddish colours; used for bridge-building, finer walls, &c., Best building-stone . . . . . . . . . . . . . . . . . . . . . . . . | 9 | 6 |
| Grey Freestone . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . | 7 | 6 |
| Good light yellow Freestone, much preferred from its colour, underlaid by a thin seam of clay, the only wayboard in the quarry . . . . . . . . . . . . . . . . . . . . . . . . | 11 | 0 |
| Good white Freestone . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . | 2 | 10 |
| Strong white Freestone; white with minute yellow grains . . . . . . . . . . . . . . . . . | 8 | 0 |
| Sandy and bad Freestone . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . | 2 | 0 |
| Bad Stone; sometimes used for walls, bridges, &c.. . . . . . . . . . . . . . . . . . . . . | 9 | 0 |
| Soft yellow Sandstone, grains of sand cemented by a small quantity of decomposed felspar. | 4 | 6 |
| Sandstone of deep red colour in massive beds sunk through in search of water. . . . . . . | 222 | 0 |
| Total feet . . . . . . | 311 | 7 |

[1] Quarries of light-coloured sandstone sometimes of a delicate yellow colour, at others inclining to an olive tinge, and like the rock at Grinshill subordinate to the New Red Sandstone, occur at Runcorn, Cheshire, and at Warwick.

[2] Aikin, MSS., note.

[3] All the modern edifices in and around Shrewsbury are built of this durable light-coloured sandstone, the finest beds of which are so susceptible of being worked for the highest ornamental purposes, that the column and statue of General Lord Hill are both formed of them. The pillars in the colonnade of Onslow House, the residence of Colonel Wingfield, offer a beautiful example of the slightly tinged pink variety.

Water is scarce along the edge of the escarpment, which has occasioned sinkings to be made at Grinshill in the red sandstone to the depth, as already stated, of 222 feet below the base of the quarry, when the borings were still in that rock. Mr. Aikin, however, well observes, " a circumstance remarkably characteristic of this kind of sandstone, is the great number of meres, or deep pools, which it contains. The outline of all these pools more or less approaches to circular; they receive no streams, and very often do not transmit any, the loss by percolation and evaporation being nearly supplied by the springs that occupy the middle and deepest part of their bottoms; I say nearly, because all that I have examined bear evident marks of gradual diminution: in many, this change has advanced so far as to convert the whole area, with the exception of a deep pit or two near the centre, into a peat moss, and some of the smaller and shallower ones are not only entirely filled up, but are even applied to the purposes of agriculture." (Geol. Trans. Old Series, vol. 1. p. 193.[1]) The Grinshill and Hawkstone range of sandstone is much denuded to the east and south-east, sinking gradually into the plain towards Newport, but it maintains an elevated outline to the west-south-west, and can also be followed, at intervals, to the east-north-east by Market Drayton into the high district of Ashley Heath, 803 feet above the sea. (See Map.) To the west-south-west it occupies Harmer Hill, Pim Hill, and the bold rocks at Ness Cliff, from one hundred to one hundred and fifty feet high. It is there, for the most part, a thick-bedded, deep red and yellowish, loosely cohering, quartzose sandstone, composed of minute rounded grains of quartz, of yellowish or brownish colour, with here and there a scale of mica, cemented together by a small portion of red clay. Veins of small dimensions, composed of quartz, cemented by a chalcedonic paste, not unfrequently traverse the beds, projecting on the surface of the friable sandstone. Further particulars respecting these veins and the derangement of the strata, will be pointed out in a subsequent chapter, after describing the trap dykes of Acton Reynolds.

Beds of sandstone of this age are only to be seen at rare intervals in the great plain of Shrewsbury, the surface being loaded with immense accumulations of gravel, clay, sand and boulders. Such sandstones, however, occupy the northern and north-eastern portion of that plain, and are separated from the coal-fields by bands of dolomitic conglomerate and lower red sandstone. By pursuing a transverse section from the Lias of Prees, through the underlying red marls and sandstone of the Hawkstone and Grinshill Hills, and thence to the edges of the Shrewsbury coal-field, (see Pl. 29, fig. 3.) we best see the great expansion of the New Red System in Shropshire. The country between the coal-fields of Coal Brook Dale and Staffordshire, of which Shifnal is the centre, is also occupied by deep red thick-bedded sandstones, lying in a trough. (See Section, Pl. 29, fig. 13.) These central rocks of the system, further extend over all the wide tract between Stourbridge and Kidderminster, constituting for the most part a rye-land district. The blood-red soft sandstone of the latter town is a good type of

[1] These meres are supported by thin courses of marl, or superficial detritus.

them, being nearly free from mica, with occcasional partings of brown slightly micaceous marl. Some of the laminæ are filled with very minute grains of *coal* derived from the adjacent fields, the whole reposing on the calcareous conglomerates of Horsley Bank, which belong to a subjacent part of the system. (See Pl. 30. fig. 3.)

In Worcestershire, as in Shropshire and Cheshire, the Saliferous Marls underlie the Lias, and pass downwards into larger masses of sandstone which rise at a very gentle inclination into hills west of Droitwich, and extend to Ombersley and Hartlebury, where the rock is a finely grained, argillaceous sandstone, slightly calcareous in parts, of a dull red colour, with, occasionally, spots of green, blue and white. The sandstone in the adjacent parts of this district (Bromsgrove, &c.) agrees so closely, that it is unnecessary to repeat the description of it at other localities in Worcestershire. Besides, the tract is for the most part so much covered with gravel, as to render it difficult to assign precise geographical boundaries to this subdivision.

In the tract between Kidderminster and the Clent Hills, in the hills surrounding the Dudley coal-field, and again in the district ranging far to the north in Staffordshire, the central sandstones contain beds of conglomerate, chiefly filled with rounded pebbles of quartz rock[1]. The pebbles vary in dimensions from the size of a child's head to that of an almond, consisting chiefly of white and pink quartz, with others of Silurian rocks and Old Red Sandstone; the whole subordinate to, and inosculating with thick beds of deep Red Sandstone. The quartzose conglomerates occupy a great number of hills, the surfaces of which are usually much disintegrated, and hence they have afforded much of that detritus which has been spread over so large a part of the low country of Worcestershire and around the Clent and Lickey Hills. (See the concludding chapter on Gravel.) Numberless sections, however, expose these rounded quartz pebbles, imbedded in the Red Sandstone at different localities over an immense area, extending by Wolverhampton to Cannock Chase, and spreading from Birmingham on the east, to near Bridgenorth on the west, and thence into North Salop; but detailed sections of quarries, in which nearly all the materials are alike, whether near the Bar Beacon, at Himley, Wolverhampton, or at Hodnet, would only fatigue the reader and convey no real instruction. In some situations, the uniform character of these conglomerates is varied by the addition of a few pebbles and fragments of the Cambrian, Silurian, and Carboniferous systems, including trap rocks. Instances of this sort occur between Bridgenorth and Wolverhampton, but it is doubtful whether some of these beds may not rather be classed in the inferior divisions of the New Red System. There is a prodigious accumulation of quartz pebbles, resulting from decomposed New Red Sandstone, at Wallsall, where they cover indiscriminately Silurian limestones, and coal measures; indeed, in this and many other parts of the coal-field of Staffordshire,

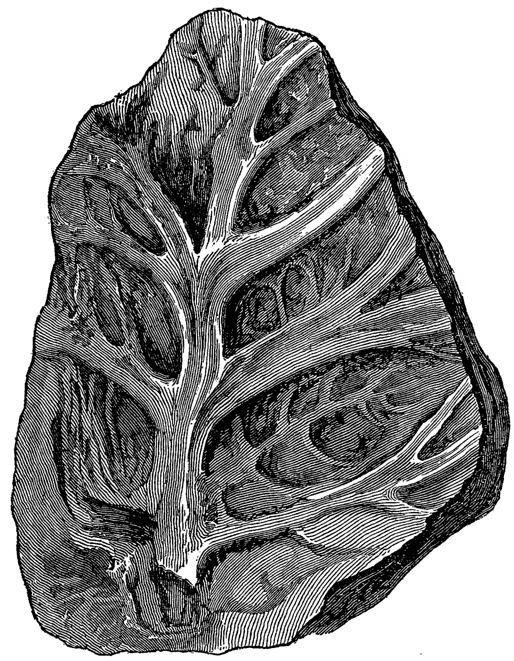
[1] Good sections of these beds are exposed on the sides of the road from Stourbridge to Kidderminster. In some of the red sandstones near the Lickey, grains of black oxide of manganese are disseminated, as in the sandstones of Shropshire. (p. 38.)

it is often difficult to determine, whether the New Red Sandstone is there *in situ*, or whether the surface is merely covered by its disintegrated materials. (See Section, Pl. 37. fig. 3.)

Animal organic remains have not yet been recognised in this division of the New Red System in Great Britain, but in a rock of the same age at Rhone Hill near Dungannon in Ireland, a profusion of small fishes (*Palæoniscus catopterus*[1] of Agassiz) were recently discovered.

Although I have little doubt that future researches will bring to light fossil vegetables from the central masses of our New Red System, I am as yet acquainted with one plant only, found in strata of this age at Liverpool, a specimen of which is in the Museum of the Literary and Scientific Institution of that town, and was, at my request, recently submitted to the inspection of Professor Lindley, who has figured it in the Fossil Flora, vol. iii. t. 201. naming it *Dictyophyllum crassinervium*. The accompanying wood-cut is taken from the drawing prepared under Mr. Lindley's direction, and he thus describes the fragment.

8.



"The specimen is that of a leaf of considerable size, of which only a portion of the upper end remains, the end itself and all the margin being broken off. It bears a striking resemblance to the leaf of some of the thick-ribbed cabbages, consisting of several elevated ribs, full three quarters of an inch wide, which spring at an acute angle from a midrib of about the same thickness, and divide towards the point into two or three

[1] Geol. Proc., 1834–5, vol. ii. p. 206. The fish quarries of Rhone Hill were visited by Professor Sedgwick and myself, accompanied by Mr. Griffith, Lord Cole, and Colonel Montgomery.

branches, besides in one place putting out lateral ribs near the base. Intermediate to the principal ribs are, in one place transverse connecting elevations, which we may suppose to have been secondary veins; and in another place a small vein with lateral veinlets. In the whole specimen there is a good deal of irregularity of arrangement in the parts, and a greater want of symmetry than is usual in leaves."

Although the Upper Formations of the New Red System in England afford few traces of fossil plants and animal remains, the strata of the same age in France and Germany contain a flora and fauna of peculiar character. Many of the plants are already figured by M. Adolphe Brongniart, in his great work on fossil botany, "Histoire des Végétaux Fossiles." The Keuper, for example, presents several species of *Equisetaceæ* of the genera *Calamites* and *Equisetum*, and a fern of the genus *Pecopteris*.

The Muschelkalk contains a species of fern, *Neuropteris*, and *Mantellia*, one of the Cycadeæ.

In the Grès bigarré the following plants occur. EQUISETACEÆ: *Equiseti* and *Calamites*. FILICES: *Anomopteris*, *Neuropteris*, *Sphenopteris*, and *Filicites*. CONIFERÆ: several species of that remarkable genus *Voltzia*, named after the geologist whose labours have thrown so much light on the structure of Alsace[1]. LILIACEÆ: *Convallirites*, *Æthophyllum*, *Palæoxyris*, *Echinostachys*. On the whole, these plants have a certain community of character peculiar to the deposits of this age, and are very distinct from the vegetables of the overlying or underlying systems.

One plant only of the Keuper, *Equisetum columnare*, is found in the lower part of the Oolitic System; whilst two species, *Calamites arenaceus* and *C. Mougeottii*, are common to the Keuper and the Grès bigarré.

Some of the animal remains of the Keuper have already been mentioned (note, p. 30. &c.). In the Grès bigarré, besides the saurians, to which I have alluded, there are univalve and bivalve shells, some of which are well-known fossils of the Muschelkalk.

In a masterly sketch of the red sandstone group of the Vosges and adjacent parts of France[2], M. Elie de Beaumont has shown that the upper marls (Marnes irisées), which he places in parallel with our English red marl, are the true representatives of the Keuper; and the identity between these marls of Lorraine and the Keuper of Swabia has lately been completely established by M. Levallois[3], who coincides with De Beaumont and Voltz in considering the whole formation to be composed of saliferous and gypseous marls, with occasional traces of coal and thin subordinate courses of sandstone and limestone. Thus the Keuper of Lorraine and Swabia only differs from our red marl in containing traces of coal and limestone, with bands of sandstone of greater thickness than any known in the English formation. In these regions, however, there is no ambiguity, since the Keuper is surmounted by the Lias, and is invariably separated

[1] Géognosie de l'Alsace. Strasbourg, 1827.

[2] Mémoires pour servir à une Description géologique de la France, tome i. p. 1.

[3] Mém. de la Soc. Géol. de France, tome ii. p. 1.

from the Grès bigarré by the Muschelkalk; but in the central and south-western parts of France, as the researches of M. Dufrénoy[1] acquaint us, the upper marls and underlying sandstones are brought together, precisely in the same manner as in England, the Muschelkalk or subdividing limestone having thinned out.

Judging from these comparisons of foreign types, I have no doubt that our saliferous marls in England, with their subordinate courses of sandstone, represent the Keuper and Marnes irisées; and whether or not the calcareous course of Broughton in Shropshire be ultimately referred to the Muschelkalk, still it appears certain, that all the massive sandstones underlying the marls, as described in this chapter, are the true representatives of the Bunter Sandstein or Grès bigarré; for independent of clear stratigraphical position, the great thickness and indivisibility of these sandstones seem to me distinctly to authorize this conclusion.

[1] Mém. pour servir, &c. tome i. p. 313.

# CHAPTER IV.

## NEW RED SYSTEM.

(CONTINUED.)

### 3. *Calcareous Conglomerate.*—4. *Lower New Red Sandstone.*

3. *Calcareous Conglomerate.*—Equivalents in England: *Dolomitic Conglomerate, Magnesian Limestone.*—Foreign Equivalent: *Zechstein.*

THE rocks forming the third division of the New Red System in the central counties, must, from their position, be considered of the same age as the Magnesian Limestone of the North-east, and the Dolomitic Conglomerate of the South-west of England. (*d.* of wood-cut 5, p. 28.) They do not, however, contain solid beds of magnesian limestone, and very seldom so much magnesia as to entitle them to the name of dolomitic conglomerate; but are, for the most part, simply calcareous conglomerates, consisting of fragments of quartzy, Silurian, and other rocks, as well as of carboniferous and other limestones, enveloped in a calcareous matrix.

In the Tortworth district, at the northern extremity of the Bristol coal-field, the true dolomitic conglomerate is considerably developed, and has been fully described by several geologists[1]. In the North of Gloucestershire and South of Worcester, where the the New Red Sandstone is conterminous with the Old Red, there are no distinct traces of this member of the series, unless we suppose that the few thin courses of slightly calcareous conglomerate, which occur, at intervals, near the bottom of the sandy series, be its representative. (See p. 51.)

In the great expansion, however, of the New Red System in the North of Worcestershire, in Staffordshire, and Shropshire, there are calcareous conglomerates of considerable thickness, which, as they pass beneath the great masses of Red Sandstone already described, there can be no hesitation in referring also to the age of the Magnesian Limestone. They occur in great force in the north-eastern face of the Lickey

[1] See the memoirs of Mr. Horner, Dr. Bright, Mr. Warburton, Messrs. Buckland and Conybeare, and Mr. Weaver; Geol. Trans., vol. iii. and iv. Old Series, and vol. i. New Series. This dolomitic conglomerate is also described in this work in the chapter on Tortworth, and the position is marked near the south-eastern extremity of the accompanying map.

and Clent Hills, and appear also on the northern end of the Lickey ridge of quartz rock, whence they range by St. Kenelms to Hagley. In this course they distinctly overlie a great formation hereafter to be described as the Lower New Red Sandstone, and rise high on the sides of the trap rocks of the Clent Hills. They here vary much in importance, particularly near St. Kenelms and Hagley (see Map), some masses having a thickness of fifty and sixty feet, others of not more than six or eight. At Gannow Green, near St. Kenelms, there are extensive lime-works in this rock, an account of which may suffice for those at other localities.

The beds dip very slightly to the south, and are separated from each other by sandy marls and clay. The greater part of this rock is made up of angular fragments of a pre-existing, very compact limestone, which, from the corals and other fossils found in it, proves to be the carboniferous limestone. In some parts of the quarries the rock consists of concretions of marl and fragments of sandstone and grits with coal plants, imbedded in a pink calcareous grit; but in others, of small pebbles of quartz and still older rocks, enveloped in a red, ferruginous, earthy basis, penetrated in all directions by white, crystallized carbonate of lime. The matrix and cement are throughout very calcareous, and the colour of the rock varies with that of the ingredients, from a reddish tinge, to shades of yellow and white. This conglomerate follows all the sinuosities and promontories of the Clent Hills, as is well seen between the hills of Romsley and Walton, where, associated with the Red Sandstone, it enters into a deep recess. It also folds round Hagley Park (near the parsonage), accommodating its outline to the form of the hills, where it has been described by the Rev. J. Yates as a calcareous breccia, consisting of grains of quartz, decomposing felspar, and limestone[1]. Transverse sections, from north to south across the strata, are exhibited on the sides of the roads which ascend to the Clent Hills by St. Kenelms, or by Hunnington (see Pl. 29. fig. 10.), and expose several lower calcareous courses, separated by argillaceous red marls and sandstone. Calcareous bands prevail so much in this district, re-occurring at intervals in the escarpments through a thickness of many hundred feet, that if they were all included in this division it would be impracticable to define with precision their limits, since they graduate into, and form a part of the Lower Red Sandstone, which in its turn overlies and passes into the coal measures. (Quarry Hill, Hales Owen, Colmer's Hill, Hodge Hill, see Pl. 29. fig. 10.) It will indeed be shown in the sequel, that other calcareous bands, for the most part, however, of true *concretionary* structure, are even traceable down into the coal measures; and for this reason I restrict the comparison with the Magnesian Limestone or *Dolomitic Conglomerate*, to the mass of this rock which *immediately* lies beneath the central sandstones (Bunter Sandstein, or Grès bigarré.)

Calcareous conglomerates are to be seen at many points round the outline of the Dudley and Wolverhampton coal-fields, generally at some little distance from the edge of

[1] Geol. Trans. vol. ii. p. 250.

the coal-bearing strata, and always dipping away from or overlying them; Brand Hall on the east, and Himley and Tettenhall on the west, may be cited as localities. To the north of Kidderminster the bold escarpments of the New Red System, contain calcareous conglomerates which are burnt for lime at several places, between Enville on the south and Coton on the north. At Coton and at Bowells, the rock is from twenty to thirty feet thick, and is composed of the following varieties:

(*a.*) Coarse Conglomerate, composed chiefly of fragments of carboniferous limestone, generally rounded and red on their exterior. Some of them are of an oolitic structure; others of a compact limestone, containing encrinites, corals, and terebratulæ, and discoloured partially by films of green carbonate of copper. (*b.*) Conglomerate, with fewer fragments of limestone but pebbles of quartz, Old Red Sandstone, &c.; the whole cemented by pure white, crystallized carbonate of lime. This conglomerate passes into a pink calcareous sandstone with pebbles and minute fragments of jasper.

In attempting to refer the fragments of limestone to the original rock, the oolitic structure distinctly proves, that some of them have not been derived from any formation below the Old Red Sandstone, in none of which has such a structure ever been observed, whilst the nearest known masses of a similar rock, are in the carboniferous limestone of the Clee Hills, twenty miles distant. The included fossils belong likewise to the same deposit. The rolled condition of the fragments also accords well with the belief of their having been drifted from the Clee Hills.

Calcareous conglomerates, inclosing pebbles of felspathic trap rock, form the cap of the hills on the left bank of the Severn opposite Bridgnorth, and they are found in the continuation of this ridge in Apley Terrace. At the north-eastern extremity of the Coalbrook Dale coal-fields, similar rocks occupying precisely the same geological position, are found in Nedge Hill; and again, to the east of Lilleshall Abbey, where the new mansion of the Duke of Sutherland is actually built upon them. At this point the underlying strata consist of the Lower Red Sandstone, the overlying of the ordinary red sandstone described in the last chapter. (See Pl. 29. fig. 15.) The conglomerate in this neighbourhood is not sufficiently calcareous to be burnt for lime, being chiefly composed of rounded pebbles of sandstone and quartz with some fragments of carboniferous limestone in a base of quartzose and calcareous sand[1]. Here, as in other localities before mentioned, the strata dip away from the adjacent coal-field, from which, as we shall afterwards perceive, they are separated by a great fault. (See Pl. 29. fig. 15.) The extensive denudation of the whole series of the New Red System between Newport and Shrewsbury, has obliterated all traces of these calcareous conglomerates, and they are not met with again till we reach the banks of the Meole Brook, about two and a half miles south of Shrewsbury, where a small face of the rock can be seen which was formerly quarried to burn into lime, but it is rapidly lost, dipping at about 30° under the overlying Red Sandstone. To the south and west of this spot, the relations of the various members of the New Red System which overlie the coal-bearing strata of Pontesbury, &c., are much obscured by a thick cover of coarse gravel and clay; but at Cardeston the calcareous conglomerate again rises to the surface.

From Cardeston to Alberbury the rock is displayed for nearly two miles, constituting a low ridge, which presents its escarpment to the carboniferous tracts of Wolliston, &c., whilst the upper surface dips away to the north and east, and passes beneath the

[1] The hardness of the rock is such that the workmen call it the "Devil's haster."

Red Sandstone north of the Severn, Ness Cliff, &c., (see section Pl. 29. fig. 9.[1]). The central or most calcareous part of this ridge, has been quarried through a thickness of about thirty feet, the beds dipping at an angle of 15°. The strata consist of angular fragments of compact, cream-coloured limestone (the "kernels" of the workmen) in a reddish, sandy, calcareous matrix, in which small cavities occasionally occur, lined with crystals of dolomite. Limestone containing magnesia, is abundant in some beds of the mountain or carboniferous limestone at Llanymynech and Porth-y-wain, distant only a few miles, and that rock being of older date, may have supplied many of the inclosed materials, and much of the cement of this conglomerate. Some fragments of limestone, occasionally as large as a man's head, and forming a part of the conglomerate, have, however, been derived from the breaking up of a peculiar freshwater limestone which is intercalated between the seams of coal in the adjacent carboniferous tracts of Coedway, Pontesbury, &c. (See Chapter 5.) Besides the calcareous fragments, there are small, rounded pebbles of white quartz and other ancient rocks. These additional materials become more abundant as the ridge sweeps round to Loton Park, and they are well exposed in a section on the high road from Shrewsbury to Llanymynech, where the strata dip 8° to 10° to the east. The calcareous layers, though here subordinate to sandstone, reappear at intervals through a thickness of at least 120 feet, and overlie the thick-bedded red sandstones which form the base of the whole system. This section at Loton (Pl. 29. fig. 9.) is therefore a clear and convincing proof of the true position of the dolomitic conglomerate, since it is evidently separated from the underlying coal of Coedway by the Lower Red Sandstone of Pecknell.

In the chief lime quarries of the Alberbury ridge, were formerly some slight mining trials, occasioned by finding a few thin strings of copper ore. These strings were in the vertical joints of the rock, ranging from south-south-west to north-north-east, or nearly at right angles to the direction of the strata. The sides of these joints are usually faced with upright bands of hard sandstone, termed "Burrs," which cut through the strata and are enemies of the lime-burners.

Although it has been stated in the previous pages, that no remains of shells have yet been detected in the overlying members of the New Red System of England, a considerable number of curious and unpublished species, have recently been discovered at Manchester, in beds of variegated marl[2]. These shelly marls are considered by Professor Sedgwick to lie beneath the upper and central members of the New Red System; and Professor Phillips, who has recently worked out in some detail the relations of the strata in the environs of Manchester, is of the same opinion. In a letter to myself, he

[1] This calcareous conglomerate of Alberbury has been fully described by Professor Sedgwick, and recognised by him as the true equivalent of the magnesian limestone, and its relations to the lower red sandstone established. Geol. Trans. vol. ii. p. 399.

[2] Mr. Leigh and Mr. Binney of Manchester discovered these shells, as announced in a communication which they forwarded through myself to the Geological Society.

describes these shelly marls as lying *between* the formation No. 2. of the last chapter, and the Lower Red Sandstone, and consisting of red-coloured marls, with thin-bedded, yellow or reddish mottled limestone, both concretionary and granular. "I view them," he adds, "as attenuated and deteriorated magnesian limestone, the last term of the degradation of this rock." From the observations, therefore, of Professors Sedgwick and Phillips, there can be no doubt, that the Manchester shelly beds are of the same age as the calcareous and dolomitic conglomerates of Salop, Worcester and Stafford, which are the equivalents of the Magnesian Limestone.

These marls must be regarded with great interest, as links connecting those peculiar types of the lower New Red Sandstone described in the concluding part of this chapter, with strata of the same age in the North of England, which are known to geologists through the labours of Professor Sedgwick. Among the shells from the marls at Collyhurst, Professor Phillips recognises *Axinus obscurus*, M. C., or a large variety of that species, as the most prevalent, associated with an *Avicula*, not very remote from *A. socialis* of Schlotheim; and many small undescribed univalves. The same author holds out the prospect of publishing a monograph of the fossils of the magnesian limestone, including all the species in the Manchester marls.

Having now described the three upper divisions of the series in those districts, where their characters and order of superposition are distinct, I might at once proceed to the examination of the subjacent sandstones, where they are most expanded, as around the coal-fields of the central counties. It is desirable, however, previously to invite attention, to the prevailing characters of the lower portions of the system, in Gloucestershire and the West of Worcestershire, where the system being little developed, the whole of its lower portion, consisting of conglomerates and sandstone, is so intimately connected, that it can be considered only under one head.

### *Base of the New Red System in Gloucestershire and south-western parts of Worcestershire.*

In Gloucestershire and the adjacent part of Worcestershire, the members which constitute the bottom of the system, are sandstones and conglomerates of mixed characters, sometimes slightly calcareous, at others quartzose, and occasionally containing great abundance of pebbles and fragments of trap rock, intermixed with sedimentary rocks of high antiquity. Such beds may represent either *the central Sandstones and Quartzose Conglomerate* No. 2, or *the Calcareous Conglomerate* No. 3, or *the Lower New Red Sandstone* No. 4.

This view is rendered probable, by the gradual expansion of the respective members of these deposits in their range from south to north, until they attain that great development, which constitutes the New Red System of the northern parts of Worcestershire, Staffordshire and Shropshire. Having personally traced the line of demarcation between these

red formations and the older rocks on which they rest, from Chepstow to Denbighshire, I commence by pointing out the manner in which, from small beginnings in the south, their successive development is accomplished as we proceed northwards.

In the tract between Chepstow and May Hill, the whole of the space coloured on the map as belonging to the New Red System, is exclusively occupied by the upper red and green marls, (not saliferous in that tract,) which are seen at many points in contact with Old Red Sandstone, and at Flaxley with Silurian Rocks. (Pl. 36. fig. 13.) At Huntley on the eastern side of May Hill, soft red sandstones first appear, rising from beneath the marls and separating them from the Silurian rocks; and between that place and Newent, where the sandstone attains a considerable thickness, there are traces of quartzose conglomerates occasionally cemented by calcareous matter. These relations prevail for some miles to the north of Newent, the lower beds of the system overlying a thin zone of coal measure; but in approaching the Malvern Hills, the sandstones are much more expanded, and the conglomerate near their base is of greater importance, and of different lithological composition.

In the absence of natural sections, the presence of the sandstone above the conglomerate (Grès bigarré), is clearly indicated by the "Rye Land" or sandy loams, which uniformly give a dry agricultural character to the surface of all the tracts occupied by that member of the system. Between Huntley and Lyne's Place are good sections of the sandstone, arranged in fine-grained, friable, thickish beds, of deep red colours, and containing subordinate, irregular courses of a small conglomerate, in which are fragments of the old red sandstone and inferior rocks. Some of these conglomerates are slightly calcareous, others pass into mere grits, the whole resting upon and thinning out, in light-coloured, incoherent sand. Low Hill, west of Lyne's Place, affords a clear section of these beds dipping 25° to 30° to the east, a high degree of inclination for the New Red Sandstone, though similar examples will be mentioned in following the lower beds of the system. From May Hill to Haffield Camp, near Ledbury, these rocks, with the exception of the tract near Newent, are in contact with the Old Red Sandstone; and the line of separation is defined by the nature of the surface. In some spots near Newent, the demarcation is pointed out by actual sections, exhibiting thin patches of coal-measures, interpolated between the New and Old Red Sandstones. At Pitleases, Weatherlocks, and Oxenhall, the sandy rye lands rise into eminences based upon red conglomerate and sandstone; and at the escarpment is a thin profitless zone of coal, resting upon the stiff clays of the Old Red System. In one instance, however, the new red conglomerate dipping 15° to the south-east, lies at once upon the edges of micaceous flagstones of the Old Red, which are thrown up at an angle of 70°. (Pl. 30. fig. 10.)

Clear junctions of the New and Old Red Systems are exhibited at Broom's Green and at Haffield Camp. (Pl. 29. fig. 1.[1]) At the latter place, the upper beds of the New Red consist of soft, red sandstone, and the lower of brecciated conglomerate, of a deep red colour, containing fragments of syenite, varieties of Silurian rocks, quartz rock, and Old Red Sandstone. The syenite derived from the adjacent ridge of Malvern is in much

[1] The section displaying these beds of new red conglomerate was laid open only two years ago at Haffield Camp, the quarries being south of the high road from Gloucester to Ledbury. Some of the fragments of syenite are of the size of turkey eggs, varying from that to the size of almonds. The stone is extracted for walling, and to use the expression of the workmen, "it hugs the mortar well."

greater abundance than the other materials, and gives the mass a trappean character, resembling that of the well-known Heavitree conglomerate near Exeter. The beds dip south-south-east 18°, but the argillaceous and sandy strata of the Old Red System on which they rest, are inclined in an opposite direction.

Deep red, thick-bedded, soft sandstones occupy all the country about Redmarly-Dabitot, wrapping round the southern edges of the Ledbury and Malvern Hills; but there is, here and there, (Bromesbarrow) a trace of an underlying conglomerate. Towards the east, these red sandstones pass beneath the red and green marls (Keuper) described in the preceding pages. The base of the system is ill exhibited along the eastern flanks of the Malvern ridge, being deeply denuded, and overspread by much detritus. It has been already stated that the marls of the formation are here much developed; they are indeed prolonged so far to the west that a small space alone is left for the sandstones. This is well seen on the road from Tewkesbury to Ledbury. The red sandy and conglomerated beds are, however, visible in one or two spots, at and near Great Malvern, on the upper side of the main road, adhering to the steep slopes of the syenite. A farm-yard north of the Foley Arms, has been excavated in the surrounding rock, which on one side of the yard is a soft deep red sandstone, with a thin band or two of fine conglomerate[1], the beds dipping 35° east-south-east; on the southern side the section is less clear, owing to dislocated masses of red and green marl, which are subordinate to the sandstone, but apparently the inclination is equally high. The inference to be drawn from this high inclination of the beds of the New Red Sandstone, at a height of four to five hundred feet above the plain, will be pointed out in the chapter upon the Malvern Hills.

The foundations of many of the houses along the lower terraces of Great Malvern, are excavated in the deep-red sandstone which overlies the fine conglomerate; but the succession of strata, in ascending order, cannot be accurately observed, owing to superficial detritus. Between Great Malvern and Worcester the marly or upper division of the New Red System (*Keuper*) is much expanded, occupying the Old Hills and Madresfield, and overlying the red sandstone we have been considering. To the west and north-west of Worcester these marls are much obscured by gravel, and it is only near the base of the system that we can observe the true relations of the strata, which are occasionally exposed, resting on the ridge of Silurian rocks which connects the Malvern with the Abberley Hills.

The banks of the Leigh Brook where it issues from the Silurian ridge, north-east of Old Storridge Hill, afford good natural sections of dark red, thick-bedded sandstone, and the sides of the deeply channelled lane ascending towards Patches farm, expose beds of a brecciated conglomerate, dipping at a *high angle* to the north-east. The chief ingredients of these beds are angular fragments of old rocks, especially of the shelly Caradoc sandstone of the adjoining hill of Old Storridge. They are occasionally imbedded in a red and green calcareous cement, and layers of red and green marl sometimes occur, subordinate to the sandstone and conglomerate. The line of demarcation of the New Red from this spot towards the north, follows the sinuosities of the Silurian ridge, but rises in certain spots, as at Great Malvern, some hundred feet above the plains of Worcester. Between Ravenshill Green and Bate's Bush, is a light green, flaggy, micaceous marlstone, with a little *gypsum* and in the high lands to the north, some of the beds of red and green marl, which overlie the zone

[1] The fragments in this conglomerate vary from the size of walnuts to peas. They consist chiefly of ancient depository rocks and Old Red Sandstone. Syenite is rare in it, and the fragments are small and angular.

of sandstone are highly inclined. At Black's Well, near Knightwick, where the Silurian rocks subside for a short interval, are extensive quarries of a lightish red sandstone, speckled with yellow grains, and of a very superior quality. This thick-bedded, though finely laminated sandstone, dips 18° south-east; the angle of inclination having decreased with the depression of the ridge of older rocks against which it rests.

Almost adjoining the sandstone of Black's Well, and constituting the southern side of the gorge at Knightsford Bridge, through which the Teme escapes from Herefordshire into the plains of Worcestershire, is a remarkable cliff called "Rosemary Rock," the summit of which is about three hundred and fifty feet above the sea. At this spot, the Old Red and New Red Sandstones are again conterminous, being separated by only an alluvial meadow. (See Section Pl. 29. fig. 4.) The northern face of Rosemary Rock, is the finest vertical section of the coarse conglomerate near the base of the new red, with which I am acquainted. The fragments vary from a large size to that of almonds, and are both rounded and angular; the greater number and largest, consisting of a purple coloured, concretionary trap, hereafter to be described, which occurs in the hills of Barrow, Woodbury, and Abberley, the northern prolongation of the Malvern ridge. The other fragments are chiefly referrible to the Silurian system, and among them are quartz rock, indurated schist, and other altered rocks. The cement is partly calcareous, with a few veins of white calcareous spar. On a hasty inspection, this rock and others resembling it along this chain of hills, (as at Haffield Camp described p. 51,) might be mistaken for the trap rocks, from which they have been partly derived, but the admixture of fragments of stratified rocks of the Silurian and Old Red Systems, distinctly proves its regenerated character. The summits of those hills lying to the north of the Teme, which are marked in the map as trap, exhibit, on the contrary, no fragments except those of a peculiar rock, predominant in this range and in the Clent Hills.

At Collins Green, conglomerates like those of Rosemary Rock, associated with beds of deep red sandstone, rise to the same height as the ridge of Silurian rocks, from the flanks of which they dip 20° to 25° south-east. In this conglomerate are also many portions of silicified schist, quartz rock, and altered Silurian rock. The Silurian and trap rocks subsiding to the west of Martley, the New Red Sandstone is again conterminous with the Old, and with the depression of the older and intrusive rocks, we find a corresponding absence of coarse conglomerate and trappean fragments; the deep-coloured, thick-bedded sandstone of Martley, being nearly free from all pebbles and foreign fragments. In the north-western parts of Worcestershire, the New Red System begins to expand; and conglomerates, such as those described, are partially underlaid by soft red sandstone, both on the eastern flanks of Walsgrove Hill near the Hundred House, and at the termination of the Abberley Ridge (the Round Hills). Thence to the north, the boundary line of the New Red Sandstone comes in contact with the stiff clays and flagstones of the Old Red, but within two miles of Bewdley, it begins to flank the coal measures; and other examples of the angular coarse trappean conglomerate or breccia occur, the fragments of

trap having been derived, it is presumed, from Stagbury Hill. A similar rock is found at Warshill on the left bank of the Severn, also rising up on the edge of the Lower New Red where it is bounded by the Old Red Sandstone, the conglomerate being interposed between the intrusive rock and the soft sandstone of Kidderminster[1]. The same conglomerates, subordinate to, and winding through masses of thick-bedded sandstone, are instructively displayed at Winterdine, near Bewdley; and contain fragments of coal-measure grits and concretionary trap, both of which rocks being *in situ* adjacent to the conglomerate are of *angular* forms, whilst the quartz and pebbles of older rocks, which have been transported from greater distances, *are rounded.* These strata are unconformable to the adjoining sandstone and grits of the coal measures, and pass beneath the red sandstone, which forms the cliffs on the left bank of the Severn, and ranges to the town of Kidderminster. (Pl. 30. fig. 2.)

I have thus attempted to show, that to the south of Kidderminster and Bewdley the lower limit of the New Red System is usually marked by certain conglomerates resembling those of Devonshire, which I agree with Professor Sedgwick[2] in considering as distinct from the Lower New Red Sandstone or Rothe-todte-liegende. We may, therefore, proceed to the consideration of the structure of these tracts where natural sections exposing a full development of the lower members of the system, exhibit, besides the calcareous and other conglomerates before described, the Lower New Red Sandstone as a great and distinct subjacent formation of sandstone, marl, and shale, with subordinate courses of impure concretionary limestone, the whole passing down gradually into the carboniferous system.

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4. *Lower New Red Sandstone.*—Foreign Synonyms: *Rothe-todte-liegende* (Ger.), *Grès des Vosges—couches inférieures?* (Fr.)

When fully developed, as in the tracts of Worcestershire, Staffordshire and Shropshire where I shall now describe it, this formation differs essentially in lithological structure from any rocks we have previously considered. (*e.* of wood-cut 5, p. 28.) As a mass it may be said to consist of sandstones and grits, chiefly of a red colour, sometimes argillaceous, very frequently calcareous, associated with deep brown red shales and marls, occasionally spotted green. Grains of whitish, decomposed felspar, are frequent in a matrix of dull

[1] The trap rocks of Stagbury and Warshill are similar to those of Abberley and the Clent Hills. (See subsequent account of similar rocks in the coal-field of the forest of Wyre, chap. 9.)

[2] See Professor Sedgwick's view of the Red Conglomerates of Devonshire, Geol. Trans. vol. iv. p. 383 et seq. Since that memoir was printed, Professor Sedgwick and myself have visited Devonshire, and our opinions are expressed in the concluding part of this chapter.

red sandstone, iron in various states is here and there disseminated, and bands of impure concretionary and mottled limestone re-occur at various levels. Towards the base, many fragments of impressions of plants appear in beds of sandstone, which graduate into other and lower strata, containing thin seams of coal, from which there is a conformable descending passage into the true carboniferous system. (*f.* of wood-cut 5, p. 28.) In general these rocks contain much argillaceous matter, which on decomposing gives a striking resemblance in the surface of the country, to those tracts which are occupied by the Old Red Sandstone; whilst some of the calcareous bands above mentioned, are associated with hard flagstones. So completely, indeed, do these bands resemble the cornstone of the *Old Red* Sandstone, that they were formerly described from a part of this very tract as belonging to that formation[1]. There is now, however, no doubt respecting their age, since besides their clear superposition to the coal measures, some of these beds contain fragments of mountain limestone, and sandstones with coal plants. This is one of the many proofs (ample testimony of which will be found throughout this volume,) of the danger of testing the age of rocks, by any peculiarity in their *mineral* character, however striking; for the graphic description of the cornstone of the Old Red Sandstone, given by Dr. Buckland, is derived from specimens now proved to belong to the *New* Red System. I cannot, however, make this observation without remarking, that the mere lithological character of many of these beds might still mislead the most practised geologist, if he had not worked out the relations of all the other rocks of the district[2]. Upon the eastern face of the Clent Hills, the Lower New Red appears as a highly argillaceous red sandstone, underlying the chief bands of calcareous conglomerate of Frankley and Gannow Green, and dipping away from small patches of coal, on the north-eastern face of the quartz rock of the Lickey Hills, and at the southern end of the great Dudley coal-field. (See section, Pl. 37. figs. 7 and 8.) There is distinct proof in both tracts, that the Lower Red Sandstone is conformable to, and passes into underlying coal measures; but as the latter are of very poor quality, and are in fact mere layers of carbonaceous matter, they have in most instances not been wrought, whilst in others where they have, the works being abandoned, the relations are but little known. It is certain, however, that to the east of Rubury Hill (Lickey), the strata dip to the east at a slight angle, and pass with apparent conformability

[1] Geol. Trans., Old Series, vol. v., note p. 512.

[2] In my own case, for example, I am bound to acknowledge, that misled by mineral characters in the first year of my survey, I laid down an adjacent tract of the Lower New Red, as Old Red Sandstone, an error which I only rectified by working out the relations of all the surrounding rocks. Mr. Greenough in the table of superposition illustrative of his map, *has* noticed the occurrence of cornstones both in the New and Old Red Sandstone. It may be stated, that the inhabitants make no distinction between the half-concretionary, half-conglomerate calcareous masses in the New, and those in the Old Red Sandstone. In the country, however, of the Old Red Sandstone, the name of "Cornstone" is restricted to the coarse, sandy, conglomerate-like masses, and is never applied to the large concretions of purer limestone.

beneath the Red Sandstone. Between Hales Owen and Hagley, at Wassall Grove and Lutley, poor coal seams are apparent in natural sections, forming the lowest portion of this system, or top of the carboniferous strata, and dipping beneath the conglomerate and red sandstone of the St. Kenelms and Clent Hills. (See Pl. 29. fig. 10.) Among the most instructive excavations opened in these rocks, are those of the Quarry Hill south of Hales Owen, where thick-bedded, red, gritty sandstones, both soft and hard, are extracted for troughs, slabs, and building purposes, and contain irregular thin seams, filled with minute fragments of coal; whilst lower beds rising from beneath, pass into layers of hard grey grit, in parts calcareous, their surfaces being covered with fragments of coal and impressions of stems of plants. From these beds, there is a gradual passage into the coal tract of the neighbourhood of Hales Owen. At Coleman's Hill and Hodge Hill, in the same district, there are other sections, the strata in which, though differing somewhat in mineral characters, belong to this lower division of the New Red System; and these also exhibit passages into the coal measures. At Coleman's Hill, the upper beds consist of yellowish, soft, gritty sandstone, containing some small calcareous fragments, a few pebbles of quartz, blotches of red shale, and fragments of sandstone with impressions of stems of plants [1]. This sandstone graduates into thick-bedded calcareous grit, spotted with bluish grey, black and yellow colours, and partially burnt for lime. The spotted appearance is due to fragments of coaly matter, mixed with imperfect concretions of crystallized carbonate of lime and blotches of ochreous decomposing sandy matter. The sandstones of this age occupy a distinct ridge from Hodge Hill by the Two Gates, to near Hales Owen. They are for the most part of a yellow colour, are very cellular, and are not unlike portions of this part of the system in the county of Durham, which Professor Sedgwick has identified with the rothe-todte-liegende. I allude particularly to the soft, white, yellow and red sandstones on the banks of the Wear, at Clacks Heugh, &c., near Sunderland. On the sides of the gulleys, poor and thin seams of coal are exposed; and one of them occurring in grey calcareous breccia, similar to that of Coleman's Hill, is made up of fragments of coal sandstone, schist, and limestone, in a calcareous cement. In the bed of a brook under Wassall Grove, I observed a seam of this coal three to four inches thick, overlaid by what may be termed a *carboniferous cornstone*, somewhat resembling that of Coleman's Hill, and containing small interspersed fragments of bituminized vegetable matter, rounded and apparently water-worn, like the pieces of drifted wood seen upon the sea-coast. The calcareous bed passes upwards into thin-bedded, brownish yellow sandstone, weathering to a reddish colour. In the fine natural sections seen as we descend

[1] Mr. W. Hamilton, then Secretary to the Geological Society, accompanied me in one of my visits to the district around Hales Owen, and he can bear witness to the quantity of impressions of stems, &c. of plants which we observed in the strata of the Lower New Red Sandstone. Specimens of these may be obtained in the Quarry Hill and Coleman's Hill.

from these hills of yellow sandstones, to the edge of the great Dudley coal-field, whether from the Windmills and Two Gates, or from Hodge Hill, we find the following succession:

1st. Beds of incoherent soft yellow sandstone, with calcareous courses and thin seams and fragments of coal.

2nd. Argillaceous strata, generally red, and of considerable thickness.

3rd. Sandstone, alternating with a peculiar trap-tuf. This rock sometimes assumes spheroidal forms, and will be further described in the chapter on Dudley. It contains quartz pebbles, and fragments of coal plants, is often highly ferruginous, and passes down into strata containing small concretions of ironstone.

4th. Calcareous shale with seams of coal, which have been, and are still worked. (See Pl. 37. fig. 6.)

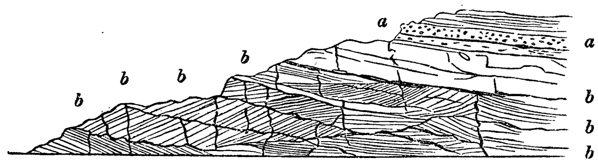
It appears, therefore, that between Hagley and Hales Owen, there are all the proofs of a Lower New Red Sandstone, distinctly underlying the masses described in the previous pages, and passing down into carboniferous strata so gradually, that it is difficult to draw the line of separation, or define it with any accuracy upon a map. As this Lower New Red approaches the Clent Hills, it is inclined to the south, and is there surmounted by the calcareous conglomerate or central and upper strata of the New Red System. At whatever point we fix the limit between the overlying sandstones and the coal measures, it must be borne in mind, that the only carboniferous strata into which these beds graduate in this immediate neighbourhood, constitute the poor and slightly productive end of the Dudley field, and that speculation in search of coal seams by sinking to great depths beneath the Lower New Red in this tract, would be quite ruinous, since we know, that the mineral thins out to mere shreds in its course to the south. (See sections, Pl. 37. figs. 7 and 8. and further explanations of this point in the chapter upon the Dudley coal-field.) In following the margin of the great Staffordshire coal-field we invariably find, that wherever gravel and superficial detritus does not obscure the relations of the strata, a zone of red sandstone, sometimes of considerable thickness, is interposed between the coal and the calcareous conglomerate. At the Stand Hills, it is a hard, greyish, partially reddish, and slightly calcareous sandstone, with a few blotches of yellowish marl, and some veins of white carbonate of lime, passing upwards into a pebbly, deep red, soft sandstone. At the Straits between Himley and Turner's Hill, it is a thick-bedded, deep red, soft sandstone, in parts slightly calcareous, full of irregular joints, and those numerous transverse striæ or lines of false bedding so common in the New Red Sandstone, with occasional lumps of harder calcareous grit. At Sedgely, it is a hard, red, slightly calcareous sandstone, with spots of green, passing upwards into red argillaceous marl. These localities are all on the west side of the field, and the strata invariably dip to the west, or from the underlying coal measures[1]. On the eastern side of the coal-field, these sandstones are much more obscured by

[1] See also the section from Wolverhampton to the banks of the Severn north of Bridgenorth, Pl. 29. fig. 13.

coarse gravel, but in several situations they are seen to be overlaid by a red calcareous conglomerate, which also dips away from the coal-field, or to the east. The great thickness of these lower sandstones has been recently proved by a spirited undertaking of the Earl of Dartmouth, at Christchurch near West Bromwich, to sink through them to the coal. These workings descended through a variety of red and spotted sandstones, blotchy deep red and variegated marls, and thick courses of red calcareous grit, concretions of impure limestone (cornstone), and ferruginous, deep red, hard, calcareous sandstone, the fissures in the rock being sometimes coated with crystals of pink-coloured sulphate of barytes, and sulphuret of iron. At my last visit, the shafts, then at a depth of two hundred yards, were passing through a light red micaceous sandstone, in which blotches of ferruginous marl were mixed with grains of carbonaceous matter. Some of the layers of this rock were separated by laminæ of black mica; concretions of calcareous sandstone, as round as cannon balls, occurred at intervals, and altogether there was so much calcareous matter as to give the rock a very concretionary aspect. The reader will perceive, that these are the very same strata which overlie the coal in natural sections at other places; and hence there could be little difficulty in predicting, that coal measures would be found beneath them, particularly as it is well known, that the coal seams of the adjacent field of Dudley, do not deteriorate or thin out in the vicinity of these works, but are simply lost by faults. The existence of the upper beds of coal having first been ascertained by borings carried down to a depth of more than seven hundred feet below the surface; they (and the lower beds) have since been reached by sinkings, an account of which, with a full description of the strata passed through, will be given in the chapter on the Dudley coal-field. (Pl. 37. fig. 1.) It is indeed impossible to mention this enterprise, without congratulating geologists on the effect which their writings are now producing on the minds of practical men; since it was entirely owing to inferences deduced from geological phænomena, that this work was commenced, whilst its success was derided by many of the miners of the adjacent coal-field[1].

In the eastern parts of Shropshire between Enville and Bridgenorth the Lower Red Sandstone occupies low terraces and depressions beneath the calcareous conglomerate, and at Shatterford is conterminous with a thin band of coal measures. The uppermost strata are so very similar to those of the great mass of rock above the calcareous conglomerate, that the description of the one, may almost serve for that of the other. Thus, for example, in the cliffs opposite Bridgenorth, and in the mass of rock on which the town itself is built, the beds possess nearly all the characters of the sandstones in the higher part of the system, being thick-bedded, soft, of a deep red colour, and traversed by innumerable lines of false bedding, which often meet in wedgelike forms; thus:

[1] The Earl of Dartmouth commenced these works at the suggestion of his principal agent Mr. Dawson, a most intelligent gentleman, but not practically versed in mining affairs, who simply applied in this case the knowledge he had derived from geological writings.




*a.* Calcareous Conglomerate. *b.* Laminæ of deposit in the Lower New Red Sandstone.

I may here remark, that whether considered in its central or in its lower member, there is no system of rocks, which occasionally offers greater difficulties for determining its real laminæ of deposit than the New Red Sandstone. Besides the joints or fissures, the diagonal lines of false stratification are sometimes so prevalent, that it is only by tracing at wider intervals the true laminæ of deposit, *b. b.* (wood-cut), as marked by herbage or moss, that we can correctly ascertain the real dip of the strata. As these appearances sometimes reoccur, from top to bottom of cliffs two and three hundred feet in height, and as the intervals between the true beds is often fifteen or twenty feet, it at first sight does not seem easy to assign an adequate cause for the accumulation of such a vast number of interjacent laminæ, parallel to each other in separate wedges, yet divergent from the lines of true bedding. Such appearancs are to be found, to a certain extent, in rocks of all ages, and however difficult it may be, to explain the precise method, by which water can have deposited the grains of sand in these positions, we have positive evidence of precisely similar phænomena, not only in young tertiary deposits like the crag, but also in those accumulations of the modern æra, which having been formed under the sea, have subsequently been raised up, and occupy low cliffs along certain parts of the coasts of our island[1].

To the south and north of Bridgenorth, the other strata of the Lower New Red, as exposed on both banks of the Severn, are similar in all respects to those described elsewhere, consisting of brownish, red, argillaceous and calcareous sandstones, flaglike, calcareous grits, with occasional underlying, slightly red and yellowish sandstones, not unlike certain coal grits. Before, however, we take leave of this tract, a little more detail is called for, respecting the relations of the Lower New Red to the south of Bridgenorth, where the formation has been generally confounded with the Old Red Sandstone; though it is clearly separated on many points from that system by a zone of coal measures. Such is distinctly seen at Chelmarsh, where a ridge consisting entirely of the Lower Red Sandstone, and associated beds of calcareous concretions, overlies in conformable apposition, and graduates downwards into strata containing

[1] See description of a raised beach on the north coast of Devonshire, by Rev. Professor Sedgwick and Mr. Murchison, Geol. Proceedings. (Vol. ii. No. 48.) Mr. Lyell has given an ingenious explanation of the manner in which these transverse laminæ may have been formed by water, in showing how similar inclined planes of sand are accumulated by wind. (See a full examination of this form of stratification, with numerous analogies drawn from the formation of the crag, in Lyell's Principles of Geology, Fourth Edition, vol. iv. p. 91.) Mr. De la Beche also throws light on the origin of this false bedding. (See Theoretical Researches in Geology, p. 88.)

seams of coal (Borle-brook). The descending order on the western slope of Chelmarsh common is as follows: See Pl. 30. figs. 1. and 4.

1. Red sandstones passing into calcareous conglomerates, sometimes of concretionary structure, (summit of ridge from Chelmarsh to Higley).
2. Argillaceous marls and clay, with beds of whitish sandstone, occasionally with green grains.
3. First traces of coal measures, viz. dark and grey shale and light-coloured sandstone, with seams of coal, too poor to be worked.
4. Top coal of this district, *twenty-two* inches thick, the highest bed in use.
5. Calcareous concretions of grey and green colours, resembling certain varieties of the cornstone of the Old and New Red Systems; a band of this limestone is seen in the bed of the Borle-brook dipping under the top coal.
6. Lower coal, two feet six inches thick, with associated measures, lies at some depth beneath the limestone, but is not now in work.

All these beds, from the lower coal to the overlying red and green sandstone with calcareous conglomerate, dip to the south east, about four inches in a yard[1].

This is indisputably one of the clearest natural sections in the range of the Lower New Red Sandstone, exposing a passage downwards to the coal measures. As these argillaceous beds with calcareous concretions, are thus proved to belong to the Lower New Red Sandstone, we thereby determine the age of other sandstones, which distinctly overlying them, occur on both banks of the Severn, at Higley, Stanley, and Alveley, and which most geologists, (myself included during my early examinations of this tract,) erroneously considered to belong to the Old Red Sandstone. Seeing the interstratification of so many beds of stiff red clay, with calcareous concretions perfectly resembling the true cornstones of the Old Red, and also beds in which the surfaces are occasionally covered with large plates of mica, it was difficult to believe that these rocks did not really belong to that System. By attention, however, to the relations of these sandstones to the surrounding strata, it becomes clear, that they belong to the New Red System; for besides the proofs of their superposition in this tract, they may be traced pursuing the same course and uniting with the sandstones of Hagley, the Clent Hills, Hales Owen, and the strata which surround and overlie the coal-fields of Coal Brook Dale and Shrewsbury.

*Grindstones.* The red sandstone of Alveley, Higley, and Stanley, which contains calcareous concretions or cornstones (several masses of which are burnt for lime at Low and Shropshire farms) is a thick-bedded sandstone, without mica, the lamination frequently marked by purple stripes, with here and there, half-formed, small concretions of green and red marl. The coarser or gritty beds are very largely quarried for grindstones, which are used at Birmingham in the manufacture of gun-barrels. The grind-

[1] The Rev. T. England first made known this section, and showed the existence of concretionary cornstones in these coal measures. Geol. Proceedings, vol. ii. p. 20.

stones are not unusually three and a half feet thick, by ten or twelve in diameter[1]. These grits are frequently calcareous, and are composed chiefly of grains of deep red quartzose sand with white specks of decomposed felspar. Although, therefore, they do not much resemble the ordinary strata of the New Red Sandstone, they are unlike any beds in the Old Red System. And though it may be difficult, nay, in some cases impracticable, to distinguish the calcareous concretions of the one system from the cornstones and limestones of the other, we have a safe guide in the order of superposition; and the absence of the fishes and organic remains of the Old Red Sandstone, is negative evidence of some use in assisting the inquirer.

In subsequent remarks upon the carboniferous deposits of these tracts, it will be explained, how the coal measures which appear in patches in the bed and banks of the Severn, have been brought to light from beneath this cover of the Lower New Red Sandstone. This member of the system is further developed on both banks of the Severn, north of Bridgenorth, or between that town and Madeley, leaving no doubt of its age, since it is seen overlying and dipping away from a thin zone of coal at Tasley and Coughley; and where some of the harder courses also contain calcareous sandstones. (Pl. 29. figs. 11, 12 and 13.)

A most instructive transverse section can also be made by passing from the high terrace of Apley to the lower ridges, in which are situated the park and house of Mr. Whitmore. The change observed in passing from the fine sandy and loamy soil of the upper and middle portion, to the cold argillaceous surface of the lower division of the system, is quite as marked, as the contrast between the agricultural surface of the *New* and *Old* Red Sandstones, where those systems are brought together in Gloucestershire and parts of Worcestershire. (See Map.) So complete is the resemblance between this lower member of the New Red, and the Old Red Sandstone itself, that I confess it was only the clear order of superposition which convinced me, that this zone of sandstone and clay really formed part of the younger system. Near Apley Park lodge, quarries have been opened in this rock to the depth of thirty feet, exposing a hard, greenish and deep red sandstone, in parts calcareous, in others slightly concretionary and conglomerated, the whole subordinate to stiff, red, argillaceous marl or shale. Here, as at Cantern Bank near Tasley, the beds lie *conformably* upon the coal strata, a band of which appears below in the bed of the Severn, while the superior face of the red rock dips beneath the overlying conglomerate of Apley Terrace. As Mr. J. Prestwich, to whose labours in this coal-field I shall have occasion to allude hereafter, has discovered plants in these Lower Red Sandstones; the analogy to the strata of similar age near Hales Owen, Hagley, Shrewsbury, and other places, is complete.

On following this rock to Coal Port Bank, we there see it exhibited in deep vertical sections. Thick- and thin-bedded, red, argillaceous sandstones; yellowish and greenish grits, occasionally calcareous, with wayboards of argillaceous marl, constitute the upper cliff, dipping to the east 10° under an argillaceous cover, and resting upon thick-bedded red sandstone, having a slight tendency

[1] The stone was also formerly much extracted for the furnace hearths of blast-houses, but experience has taught the iron masters, that many other sandstones are equally serviceable for that purpose. The coarser beds contain small fragments and concretions of marl. They are also used as building-stones.

to conglomerate structure[1]. The other varieties of this rock contain rounded grains of quartz, and white specks, probably of decomposed felspar, with a little iron pyrites, in a calcareous paste, together with bands of coarse-grained pebbly grit and specks of chlorite, in a cement of white crystallized carbonate of lime. Some of the calcareous grits enclose concretions of green and red marl, thus resembling the impure cornstones of the Old Red Sandstone. Between Coal Port and Madeley this sandstone is affected by powerful faults, to the chief of which I shall advert in a subsequent chapter; it being enough for my present purpose to state that along the boundary of this field, as in Staffordshire, great dislocations equally affect the carboniferous strata and the Lower New Red Sandstone[2]. A transverse section from Sturchley to Shifnal, across Nedge Hill, like those previously cited, exposes sandstones and flaggy grits both green and red, and thin courses of slightly calcareous conglomerates and flagstones, associated with much argillaceous marl; the whole passing beneath the younger group of Shifnal, &c. The country around Shifnal, Sheriff Hales, and Crackley Bank, is covered with the quartz pebbles of the disintegrated conglomerate, beneath which a dark-coloured, finely laminated, soft, sandstone is seen at intervals; but these beds, as well as all those situated midway between Bridgenorth and Wolverhampton, and occupying points intermediate between the coal-fields of Staffordshire and Coal Brook Dale, belong rather to the overlying or great central mass of sandstone. At Lilleshall, the same instructive section, as that from Nedge Hill to Shifnal, is repeated with still greater clearness and fuller development (Pl. 29. fig. 15.) In the slopes of the hills below the terrace on which Lilleshall House is built, are stiff, argillaceous beds which produce a cold and unmanageable soil. Other sandy beds, on the contrary, are quite incoherent and very largely micaceous, a rare feature in the supracarbonaceous strata. At Lilleshall Abbey, the lowest strata apparent on the surface are thick-bedded, light brownish sandstones. The junction of these with the underlying coal has never yet been ascertained, but there can exist no doubt of these being the true beds of passage into the carboniferous system. Portions of this sandstone are seen at one or two points along the northern flank of the Ketley portion of this coal-field, and they follow the outline of the promontories of the trap and Silurian rocks near Wellington, but are for the most part in an incoherent and decomposed state, and the district is also much obscured by gravel. The lower red sandstone reappears at Wroxeter, Preston Boats[3], Shrewsbury, and at other places upon the banks of the Severn. (See Map.) It dips away in slightly inclined masses from various small patches of coal at Pitchford and Uffington; also near Longnor, where the coal-bearing strata of Le Botwood pass gently beneath the red strata of Condover and Stapleton. In that district,

[1] There is a tradition that coal was worked immediately beneath this rock upon the south, and it is in every way probable that such was the case, seeing that the strata dip away from the coal-field of Brosely, on the opposite bank of the Severn.

[2] These are all elaborately described by Mr. J. Prestwich, in whose memoir, preparing for publication in the Geological Transactions, will be found valuable details of the dislocations of the carboniferous and associated strata in this vicinity.

[3] At Preston Boats the upper part of the old quarries exposes thin-bedded, hard, slightly calcareous beds, with small concretions of dark green impure limestone, closely resembling certain cornstones of the Old Red Sandstone. In the lower part of the quarry the beds become thicker, and consist of sandstones of deep red colour, with a few blotches of marl. It is from beds of this age, that the Abbey, Castle and many ancient buildings of Shrewsbury have been constructed. Though I have looked in vain for any traces of organic remains in these calcareous beds, we should never despair of such a discovery, when we recollect for how long a period the existence of organic remains was unknown in beds of similar structure in the Old Red Sandstone. (See observations on recently discovered plants and other remains in the New Red Sandstone of Worcestershire, p. 64 *note*.)

these red sandstones enter deeply into the recesses of the bays or denudations which have been formed at the north-eastern extremities of the Cambrian rocks, in many situations resting directly upon their vertical or highly inclined strata; while in others, as in various hollows near Cound and Pitchford, they are separated from the old rocks by thin patches and broken zones of coal. In all such positions, even at the north-western end of the Lawley and Caradoc ridge, these sandstones, where not obscured by coarse drifted gravel, are soft, thick-bedded building-stones, usually lying in slightly inclined strata. In a quarry at Condover about thirty feet of these beds, dipping very slightly to the north-north-east, are arranged in the following descending order:

1. Gravel; 2. Thin-bedded sandstone; 3. Red, argillaceous marl; 4. Sandstone; 5. Argillaceous marl as above; 6. Sandstone; 7. Marls as above; 8. Thick-bedded sandstone.

There are distinct evidences of the existence of the inferior beds of this formation, at various points west of the Wellbatch Collieries, near Shrewsbury, particularly on the left bank of the Meole Brook, where several pits and trial shafts, sunk by Mr. Hughes, have passed through,—1st, Purple, red and green sandstones, marked by blotches of marl; 2ndly, Greenish and bluish shale; 3rdly, Whitish sandstone with green grains; 4thly, Coal-bearing measures. Of the last-mentioned rocks we shall have occasion to speak in a subsequent chapter, it being now sufficient to attend to the fact, that frequent impressions and fragments of coal plants have been discovered in these overlying red and green beds, which here form the cover of the coal-bearing strata. Most of these plants, like those of the Hales Owen and Hagley tract, are in an imperfect condition; but Professor Lindley had no hesitation in considering them as belonging to the carboniferous epoch.

There are but few other spots around the southern edge of the Pontesbury or Shrewsbury coal tract, where the Lower New Red Sandstone is visible, owing to a great mass of superficial detritus; but the rock is laid open at Fairley, where it is a dark red, soft, thin-bedded sandstone, made up of black and white grains in a red paste, with a few harder concretions and some blotches of red marl. The same rock is also partially quarried at Newton near Boycot, where it is harder, more siliceous, and intractable, and it is again seen in the bed of the brook at Stretton, dipping to the north-east and north, &c., or away from the adjacent coal-field.

In the escarpment at Cardeston, the same red sandstone underlies the dolomitic conglomerate, and dips away from the adjoining coal measures. In some of the quarries, this stone is of a light brown colour and consists of fine grains of quartz, much rounded, the matrix composed of earthy matter being freckled with dark stains, probably caused by the decomposition of small nests of iron pyrites. Following this escarpment to Pecknall, west of Alberbury, this sandstone is seen to rise from beneath the calcareous conglomerate, and to form a separate ridge between that rock and the coal measures of Coed Way. It is here a thick-bedded, deep red sandstone, without mica, speckled with whitish grains of decomposed felspar[1]. Like the lower beds in other places, it is also based upon argillaceous bands which decompose to a stiff, red clay, forming the immediate lip of the coal-field, and passing down into those beds of variegated shale which immediately overlie the coal.

It may here be mentioned, that the transverse section at Alberbury and Pecknall proves, that the dolomitic conglomerate, the red sandstone, and the coal beneath it, are all arranged in conformable order of superposition, dipping to the east and east-

[1] The sandstone of Pecknall is quarried to the depth of thirty feet and is an excellent building-stone brought into use by Sir B. Leighton, Bart., of Loton Park.

north-east and resting upon the inclined edges of the Silurian system of rocks. (See Pl. 29. fig. 9.)

The western extremity of Shropshire, affords still clearer proof of the Lower New Red Sandstone being directly superposed to the coal measures; for in the new pits at the Drillt, to the east of Oswestry, red sandstone, marl, and shale, have been penetrated to a depth of upwards of one hundred yards, before the first traces of coal measures were perceived; when, after passing through several layers of impure carbonaceous matter, the usual coal seams of the Oswestry field were reached, and are now largely worked. (Pl. 30. fig. 13.) This case is precisely analogous to that of Lord Dartmouth's colliery near Birmingham, and will be enlarged upon in the eleventh chapter.

We have now gone through the New Red System, in as much detail as appeared requisite to point out its prominent features in this region; and I have attempted to separate the mass into divisions, which may stand the test of comparison with the sub-groups established in other parts of England, and with those sanctioned by foreign geologists. Closer comparisons appear impracticable, particularly as they must in the present state of our knowledge be chiefly founded upon mineral distinctions: for although one saurian animal and a few vegetable remains have been found in the sandstone of Warwick, and certain fishes have been detected in Ireland; the whole system in the central counties of England (with the exception of the shelly marls of Manchester, representing the Magnesian Limestone,) is poor in organic fossils.

Certain sandstones, however, in Worcestershire are to be exempted from this observation; for, even while these pages are going through the press, both animal and vegetable remains have been discovered in them, and will be described in the Appendix[1].

[1] Being anxious to announce the discovery of any organic remains in the upper or central members of the New Red System, many parts of which I had not examined in detail, I recently requested my friend Mr. H. E. Strickland to visit the quarries of Burg Hill near Eldersfield, the marly sandstones of which I have referred to the Keuper formation. (pp. 29 and 30.) Having done so, he has succeeded, after a minute search, in discovering "two indisputable fragments of *bone*, and *some small oval bivalves*, too indistinct to determine their genus." One of the bones proves to be an Ichthyodorulite. Mr. Strickland's section of the Burg Hill quarry is:

| | Feet. | |
|---|---|---|
| 1. Red Marl | 4 | Dip. S.W. 10°. |
| 2. Greenish grey Marl | 8 | |
| 3. Thinly laminated Marl with white Sandstone | 4 | |
| 4. Soft white Sandstone | 6 | |
| 5. Greenish grey Marly Sandstone | 8 | |
| | 27 | |

"These beds," Mr. S. observes, "thin out and vary in different parts of the quarry, the sandstone often presenting ripple marks on its surface. The marl No. 3. has been much cracked at the time of its deposition, and the crevices are filled with white sandstone in the same manner as those of septaria are with calcareous spar. From the tendency of the marl to split into spheroidal fragments, the curved fissures thus produced, when filled with the white sandstone, have very much the appearance of bivalve shells. Sometimes the marl is more broken

We may now conclude by simply recapitulating, that the previous details have shown the existence of—

1st, Saliferous and gypseous marls, with beds of sandstone, constituting together the equivalent of the "Keuper" formation of the Continent.

2nd, Sandstones and quartzose conglomerates, representing the "Bunter Sandstein" of the Germans, and "Grès Bigarré" of the French.

3rd, Calcareous conglomerate, the position and structure of which proves it to be of the same age as the dolomitic conglomerate of the South-west, and of the Magnesian Limestone of the North-east of England, and that, however differing in mineral characters, it is therefore, as shown by Professor Sedgwick, the representative of the rocks known in Germany under the names of Zechstein, Rauchwacke, &c. The trappean conglomerates on the flanks of the Malvern and Abberley Hills, are of about the age of this deposit, being clearly of younger age than the sandstones which form the true base of the system[1].

4th, That the Lower New Red Sandstone overlying the coal-fields of Staffordshire and Shropshire, though differing considerably in lithological structure, is the equivalent of those sandstones of the North-east of England, which occupy the same place as the "Rothe-todte-liegende" and probably the lower beds of the Grès des Vosges[2]. The country described being intermediate between the south-western districts of England, where the dolomitic conglomerate rests unconformably upon the coal measures, and those northern districts where the series is fully developed, it is interesting to observe the points whence the expansion commences, and to mark the gradual increase of the lower deposits of the system,

up and consists of detached angular fragments imbedded in the sandstone. The latter is commonly of very fine texture, but some specimens of coarse grit may be found, the pebbles of which (chiefly quartz) are one fourth of an inch in diameter." Letter to myself, March 11, 1837. In a subsequent letter, March 22, Mr. Strickland further announces that Mr. Amphlett, of Dunclent near Kidderminster, had discovered fossil vegetables in a stratum of "dove-coloured" sandstone, which separates the great mass of red sandstone from the overlying marls. This band of whitish sandstone, very similar to that of Burg Hill, extends along the district of Doverdale. *The plants, consisting of various genera,* were chiefly found at Elmley Lovett, and at Hadley near Ombersley, and are now deposited in the museum of the Natural History Society of Worcester. I have requested that the specimens may be sent up to Professor Lindley to be described and figured in the Fossil Flora, and conceiving this discovery to be of great importance I shall visit the localities and announce the result in the Appendix." March 23, 1837.

[1] An expression has inadvertently crept into a previous sheet, p. 30, which I hasten to explain. It is there stated, that the conglomerates in question may represent the formations 2, 3, or 4, of this System. The conglomerates here alluded to never can represent the No. 4, or Lower New Red Sandstone, but they are occasionally underlaid by a thin zone of sandstone, which possibly may be considered the feeble representative of that formation.

[2] See Professor Sedgwick's Memoirs, Geological Transactions, vol. iii. and iv. Consult also "Système des Vosges," of M. Elie de Beaumont, (Mémoires pour servir à une Description géologique de la France, vol. i.); the valuable Map of the Rhine, and "Geognostische Umrisse der Rheinländer," by Oeynhausen, Dechen, and La Roche; and the work of M. Voltz before cited.

until they attain in these central tracts an importance as great, perhaps, as that of the same deposits, in Yorkshire, Durham, and Cumberland[1].

Among the peculiarities of the Lower New Red Sandstone of this region, one of the most remarkable is the prevalent diffusion of calcareous matter, and the existence of bands of concretionary limestone, some of which pass down into the coal measures; in which respects the formation differs essentially both from its type in the North of England, and from its foreign synonyms.

A practical acquaintance with the lower member of this system, is, it must be allowed, of vast national importance; for, as these sandstones are now proved to graduate into the coal measures, we need not despair of eventually finding some of the most valuable coal seams of the central counties extending beneath them. Such results would indeed be only a repetition of the successful enterprize by which, in sinking through deposits of the same age, the south-eastern part of the county of Durham, in spite of the prejudices and predictions of the old school of miners, has now been rendered a great productive coal tract.

If such be their practical value, these inquiries may also lead geologists to modify their previous theoretical views, respecting the relations of the coal measures to the overlying rocks, founded on what must now be considered *local* phenomena, observed chiefly in the Bristol district and south-western parts of England; where because the New Red Sandstone reposes *un*conformably upon the carboniferous strata, the belief became prevalent, that this arrangement was indicative of a general rupture, *subsequent* to the accumulation of the coal measures, and *anterior* to the deposition of the magnesian limestone and conglomerate. That such, however, has not been generally the case, has been established with regard to the North of England, by the writings of Professor Sedgwick; and the preceding facts teach us the same lesson in respect to the central counties: for it is clearly demonstrated, that beds of the age of the dolomitic conglomerate are there separated from those of the carboniferous system, by an unbroken succession of intermediate strata of vast thickness, of which there are few or no traces in the south-western parts of the island.

Notwithstanding, however, the distinctions which have been drawn between the different members of the New Red System in the central counties, a question it is feared might still arise among foreign readers, concerning the true equivalent of the Rothe-todte-liegende: for as most Continental geologists conceive that formation to be essentially connected with porphyritic and other rocks of igneous origin, they can scarcely peruse the description of the trappean conglomerates, p. 51 *et seq.*, without supposing that those

[1] These subdivisions of the New Red System of this region are not always easily recognised, owing to the prevalent obscuration and small elevation of the strata; and there is great difficulty in marking with precision their separate courses with accuracy. Two subdivisions only are therefore attempted upon the annexed map, viz. 1st, Marls, Sandstone, &c.; 2nd, Lower Red Sandstone including the overlying calcareous conglomerate and the inferior courses of concretionary limestone.

masses may represent the German deposit. If, however, we are to understand the foreign synonym, to express a series of strata, elaborated in such a manner, as in some cases completely to connect the carboniferous and overlying system; then it is clear we must consider the Lower New Red Sandstone to be its true and full equivalent, even should it not contain a single pebble of trap. That it contains few or no fragments of trap in the North of England, has already been proved by Professor Sedgwick, and the same fact is now established in the central counties; whilst on the other hand the great trappean conglomerates have been shown to overlie this equivalent of the Rothe-todte-liegende, and to be on the same parallel with the dolomitic conglomerate. Referring to former opinions on this point Professor Sedgwick has well observed, "In comparing the Bristol and Exeter conglomerates with the Rothe-todte-liegende, our geologists made use of the best evidence with which they were acquainted. But the New Red Sandstone group is now better understood; and in future comparisons with Continental deposits of the same age, we should use as our types those sections which are most complete, instead of the Bristol or Exeter overlying groups, in which more than one half of the series is absolutely wanting." Geol. Trans., vol. iv. p. 400.[1]

The trappean ridges of Malvern, Abberley and Clent, will be described in the sequel; but in the mean time it may be observed, that as the red conglomerates on their flanks contain angular and rounded fragments of the trap composing those hills, the rocks from which such debris was derived, must have been in existence before the conglomerate was formed. Now, the rupture between the New Red Sandstone and the carboniferous deposits, as marked by the dislocations along the line of the Abberley Hills, would certainly lead us to suppose, that the eruptions which gave rise to these hills took place, either during the accumulation of the upper coal-measures, or of the Lower New Red Sandstone; for, without anticipating explanations which are to follow in the ensuing chapter, it may be asserted, that nothing is more consistent with modern and ancient analogies, than that such volcanic eruptions should have been mere *local* phenomena, which in the tracts where they prevailed (Devon, Abberley, Clent, &c.) may have occupied the place of the Lower New Red Sandstone, by interfering with its deposition, while in the tracts not visited by these outbursts, the formation would naturally be fully developed, and would there exhibit the unbroken connexion between the New Red and Carboniferous Systems which has been detailed in the previous pages.

[1] I may here state, that after a recent examination of Devonshire and Somersetshire, by Professor Sedgwick and myself, we were unable to separate the lower part of the New Red Sandstone of that country, into two formations, like those of the northern and central counties; and I am requested by my friend to say that he withdraws the qualifying expression (respecting the Exeter conglomerates) used in the Postscript to the memoir cited, and adheres to the opinion above quoted. (March 1837.) See Geol. Trans. iv. p. 403.

# CHAPTER V.

## TRAP ROCKS.

*Trap Rocks compared with Volcanic Products, and shown to be of Igneous origin. Distinctions between contemporaneous and intrusive Trap Rocks.*

HITHERTO we have exclusively considered the nature of *sedimentary* deposits, but our account of them can no longer be advantageously continued, without occasionally describing rocks of very dissimilar characters, which have been abundantly *intruded* amid the strata. Already indeed the fragments of some of these rocks have been alluded to as forming part of certain conglomerates in the New Red System. These are the basalts, greenstones, porphyries, and syenites, which constitute a portion of the Trap Rocks of geologists. As my readers who have not studied geology will find in the sequel, that many important inferences in the theory and practice of the science, depend on the right understanding of the phenomena connected with these rocks, I deem it advisable in this introductory chapter, to explain their analogies with the products of existing volcanoes, and to point out how they have been proved to be of igneous origin. A slight acquaintance with volcanic phenomena teaches us, that they are the results of some general and deeply seated cause, which occasions eruptions of gaseous and earthy matters, or of lava, at irregular intervals, both under the atmosphere and beneath the ocean. Hence volcanic products are naturally divisible into two great classes; sub-aerial, and sub-aqueous. The first, being in many respects open to our investigation, is to a considerable extent understood. The second, for the most part hidden from examination, is necessarily but little known, though recent observations have thrown some light upon it. It is to the last-mentioned of these classes, or submarine volcanos, that perhaps all our British trap rocks are referable. I will first very briefly point out the resemblance in mineral characters, between these rocks and modern volcanic productions, and secondly will endeavour to show, that the two classes are intimately connected with each other, both by association and physical phenomena.

1. *Mineral character, &c.* The most common ingredient in modern and ancient lavas, as well as in trap and granitic rocks, is felspar. This mineral assumes a considerable variety of forms, which differ so greatly from each other, that a novice finds it difficult to recognise in them the same substance. In an earthy, vitreous, or compact state,

it forms the basis of all lavas, and of the greater number of trap rocks. Associated with augite, and generally in a vitreous form, it constitutes some of the well-known modern volcanic basalts, in which the greater or less preponderance of the latter mineral confers the more or less black, dense, and ferruginous character which they so often assume. Mixed with hornblende it forms a large class of ancient rocks, also called basalt when the minerals are intimately blended, or greenstone when each is distinguishable. In another condition, felspar, in a glassy but loosely aggregated state, composes a rock of a rough, porous, and earthy aspect, called trachyte, which is found among both modern and ancient lavas, and formations of still greater antiquity. In a compact state, the same mineral is the base of many of the porphyries; and in a more or less crystalline form, associated with quartz, mica, and other minerals, it composes the great class of granitic rocks. As felspar is not found in any of the aqueous sedimentary deposits, except in a decomposed or regenerated state, it may therefore be considered the most characteristic ingredient of all igneous rocks. There are, however, many other simple minerals which combine to form these rocks; but it is foreign to my present object to enter into further details, it being sufficient to state, that from the above-mentioned prevalent types of rocks, formed by heat, there are endless gradations into others, on many of which I shall treat in the following chapters.

2. *Association and physical phenomena.*—In taking a general view of the association and physical phenomena of igneous rocks, let us first take a rapid glance at the method by which the products of extinct volcanos[1] have been identified in their nature, with those of volcanos in activity.

Ninety years have nearly elapsed since two French academicians, collecting plants among the hills of central France, were astonished by discovering numerous cavities, resembling the craters of volcanos. From the lips of these cavities, currents of lava, as fresh in aspect as if they had flowed yesterday, were traceable into the neighbouring valleys, following their sinuosities, barring up their ancient water-channels, and moulding themselves into the inequalities of the actual surface; and to complete the analogy with active volcanos, most of the mineral substances composing these lava currents were found to be similar to those of Vesuvius and Etna. When M. Guettard, one of the naturalists, first announced these discoveries, so unwilling were men of science to believe in phenomena, of which neither history nor tradition had preserved a record, that scepticism long prevailed. The graphic and attractive descriptions of Montlosier[2], the mineralogical knowledge of Dolomieu, supported by the precise geographical delineations

[1] I might refer to a host of writers, both abroad and at home, including the early Italian writers, who have proved trap rocks to be of volcanic origin, and in the following pages some of these will be adverted to. The elementary works of Daubeny and Scrope must be consulted by those English readers who wish to comprehend the chemical and mechanical phenomena of modern volcanos.

[2] Essai sur les Volcans d'Auvergne, Clermont, 1802.

of Desmarests[1], were all barely adequate to establish truths, which are now universally recognised, and have been rendered familiar to the British public by the beautifully illustrated work of our countryman Poulett Scrope[2]. The Eifel[3] in Germany has since been shown to be a tract in most respects analogous to Auvergne, while in Iceland are combined nearly all the phenomena which can be required to convince us, not only of the similarity of modern and ancient volcanic eruptions, but also of the *great extent* to which such phenomena have prevailed within the historic æra[4]. Besides these well-known European tracts, other quarters of the globe, particularly the continent of South America and its adjacent islands, abound in examples of the varied phenomena of volcanic action. In Asia Minor the district called the Catececaumene, described by Strabo, and recently visited by Mr. Hamilton and Mr. Strickland, presents an exact analogy with the volcanic regions of central France and the Eifel, &c. But Auvergne is not merely replete with analogies to modern volcanic regions ; it was further found to contain many rocks, which, though from their characters they must have been formed by igneous agency, are yet in many lithological features dissimilar from modern lavas, whilst they resemble many of the so-called trap rocks. Thus, for example, though many of the " lava currents " in the valleys of Auvergne are undistinguishable from those of Etna and Vesuvius, other currents, equally traceable to lips of craters, are composed of prismatic basalt very similar to the basalts of the Giant's Causeway or of the Hebrides ; and pitchstone, that ancient form of obsidian, a mineral product so abundant in some existing volcanos, has been added to the list of analogies[5]. The district further presents numberless examples of other masses, of nearly similar composition, trachytes, ancient basalts, clinkstone, &c., some of which are undistinguishable from our British trap rocks, arranged in great tabular masses at various altitudes on the mountain sides. These, unlike the more modern currents, are not traceable to distinct vents of eruption, and are in fact but the remnants of once extensive lava currents, which had flowed over the surface of this tract before the formation even of the present river courses. By such evidences, therefore, the inquirer is

[1] Carte Topographique et Minéralogique du Puy de Dôme. Paris, 1823.

[2] Scrope's Geology of Central France. London, 1825.

[3] See Hibbert's History of the extinct Volcanos of the Basin of Neuwied, 1832.

[4] See Travels in Iceland, by Sir G. Mackenzie, Bart., and Drs. Holland and Bright; also Lyell's Principles of Geology, where the author gives a vivid portraiture of the magnitude of the modern Icelandic lava currents.

[5] See Lyell and Murchison " On the Excavation of Valleys in Central France, Edin. Phil. Mag., July, 1829, p. 15. Obsidian occurs in vast quantities at the Isle of Ascension. It would appear that this substance is also very abundant in parts of Asia, where its presence had not previously been recognised, as between Anni and Kars, for example, *at a great distance from the coast*. Mr. W. I. Hamilton has recently passed through that region, and thus expresses himself concerning it : " I had always imagined, that the accounts of mountains and palaces of glass belonged only to such fables as the Arabian Nights. To day, however, I passed over the foot of a mountain of glass, and where the roads were paved with the same material. It was in fact Obsidian, or Volcanic glass, most perfect and uniform in its texture." (Letter to his Father dated June 30, 1836.)

enabled to carry backwards his researches in the same regions, through connecting links, from the existing phenomena, into volcanic products of high antiquity.

Again, many of the ancient volcanic rocks in Auvergne afford distinct proofs of having been poured into lakes, for they are interstratified and commingled with the freshwater and terrestrial spoils which constitute the lacustrine limestones and sandstones of that region; thus explaining the geological period during which they were erupted, whilst the lofty positions they occupy, on the opposite sides of deep valleys over which they once spread in continuous masses, by demonstrating the enormous amount of denudation to which they have been subsequently exposed, convey to the mind some measure of their venerable age.

In these tracts the phenomena are probably all referrible, either to subaerial volcanic action, or to vents of eruption from which currents of lava have been poured out into contiguous lakes. The latter phenomena are analogous in kind, to that greater class of subaqueous lavas which have been formed under the sea, the condition of the waters alone constituting the difference. Now, as the greater number of existing active volcanos are near the coast, so currents of lava have been repeatedly propelled into the sea. The coasts of Naples and Sicily, the latter particularly, present many examples of such currents, which have flowed into the sea in broad sheets, and have been consolidated under pressure into hard columnar lava, very similar to the basalts of older date[1].

We are thus naturally led to enter on the consideration of such volcanos of subaqueous origin, as have been attested by the sudden rise of volcanic cones and islands from the bottom of the sea. The isle of Nyoe on the coast of Iceland, the island Sabrina off St. Michael in the Azores, an island in the Grecian Archipelago, and Graham Island near the coast of Sicily, are well-known historical examples. The last-mentioned island, having been thrown up so recently as the year 1831, when naturalists were quite alive to the importance of the deductions to which its apparition might give rise, has received much attention, and the series of phenomena which accompanied its appearance and disappearance have been faithfully recorded. They may be concisely stated as having occurred in this order:

1st. The soundings of Capt. Smyth, R.N.[2], had established that the sea was upwards of 600 feet deep at this spot, anterior to the eruption.

2ndly. Ships passing near the place a short time before the eruption, were affected by earthquakes.

3rdly. Commencement of the eruption: the sea thrown up in waterspouts, accompanied by columns of steam and vapour.

4thly. The formation of a small island, at first only twelve feet high, with a central

[1] Dr. Daubeny has clearly explained how, under the pressure of an ocean sufficiently deep to prevent the formation of steam, the heat being carried off more slowly, the lava would longer retain its fluidity, and would ultimately arrange itself in crystalline forms, more or less prismatic and regular.

[2] Phil. Trans., 1832, p. 255.

crater ejecting volcanic matter and vapour, the surrounding sea being rendered turbid with floating cinders and scoria, and encumbered with dead fish.

5thly. The gradual increase of the island to 200 feet in height, and eventually to a circumference of three miles.

6thly. Its rapid diminution to a circumference of about 700 yards, when last examined by the French naturalists[1], under the erosive action of the waves and currents, which its loose fragmentary materials could not withstand.

7thly. Its final disappearance in less than three months from the period of its emergence.

8thly. The spot being surveyed in 1833, a year after its disappearance, the whole submarine remains of this mass, which had been raised from 600 feet beneath to 200 feet above the sea level, was reduced to a dangerous reef about eleven feet *under* water, in the centre of which was a black volcanic rock (probably a remnant of the solid lava of eruption), surrounded by banks of black stones, scoriæ, and sand.

In these well-recorded facts, therefore, we perceive that the eruption and demolition of this island, the apex of a cone 800 feet in height, must have covered the bottom of the sea to a great extent with detritus of volcanic ashes, scoriæ, and lava, destroying countless marine animals, and mixing up their remains with the previous materials of the bed of the sea to form subaqueous deposits. We shall hereafter advert to the value of such a modern analogy in explaining many geological phenomena, particularly in the bedded trap rocks of the Silurian System.

This slight sketch of volcanic eruptions may suffice to explain, that they could not have occurred without producing great and striking changes in physical geography. Important, however, as the volcano must be considered as a great natural means of destruction and renovation, the earthquake, its constant accompaniment, operates perhaps still more directly as an agent of change, by elevating some tracts and by depressing others, causing great rents and fissures in the strata, and giving rise to powerful variations of tides and currents, by which solid materials are transported to distant places. The volcano and the earthquake are in truth dependent on the same cause, and are but the outward signs of internal heat. The one is the "safety valve," by which heated matter escapes at intervals from the interior, the other is the shock which lacerates the solid ribs of the earth when that heated matter and its vapours, are denied an access to the atmosphere. One important task, therefore, of the geologist is to read off the proofs of these eruptions and earthquakes amid the ancient monuments which surround him on the surface of the earth; and by examining them he learns, that from the remotest time there have been volcanic eruptions, and that the framework of the planet has been repeatedly subjected to intermittent violence and fracture. He perceives that

[1] See a most instructive account of these phenomena by M. Constant Prévost, Notes sur l'Ile Julia, Mém. de la Soc. Géologique de France, vol. ii. p. 91.

many of these great eruptions and dislocations are intimately associated with other phenomena not less indicative of change. Thus within modern times, for example, irregular-shaped and narrow wedges of volcanic matter have crossed through the beds of ashes, scoriæ, and lava which envelope and form the sides of Vesuvius; and in like manner, similar masses (the dykes of geologists) are inferred to have penetrated in ancient times the solid strata of sandstone and limestone; the latter where they are in contact with the intrusive rock, being often changed into a crystalline or highly indurated state. He further perceives that veins filled with simple minerals, frequently radiate through the sedimentary rocks where they are contiguous to such centres of eruption; and thus he supplies the chemical philosopher with data, which at some future day may materially aid in solving the difficult problem of the origin of metallic veins; at least the geologist shows the extent to which such veins may have been originally dependent on volcanic action.

In our country we have no traces of subaërial volcanos; no craters like those of Auvergne, with pumice and scoriæ adherent to their sides, or streams of lava traceable to their mouths; nor have we volcanic islands rising from the bed of the sea: our only present memento of the existence of volcanic action beneath us, consisting in very slight shocks of earthquakes. On the other hand, however, Great Britain is rich in rocks possessing many mineral characters in common with volcanic products, being composed like them principally of felspar, augite, hornblende, and other minerals, and connected with them by so many gradual shades and links, that nearly all naturalists are now agreed that such rocks are the result of heat and fire. These are the syenites, porphyries, greenstones, clinkstones, and basalts, which have been forced up as molten matter through the *submarine* accumulations now constituting our sedimentary deposits[1]. Hutton, Playfair, and Hall were the first British geologists who brought the prominent features of such phenomena under the test of observation and experiment; and clearly proved that all trap dykes were of igneous origin, and had been intruded among pre-existing strata; for it was shown, that as these rocks must have been erupted under the pressure of an ocean, so ought they, instead of being light and porous, to be hard, compact, and heavy, as we now find them. Obvious as these views may *now* appear, they required much subsequent illustration and support, before they could obtain that general assent to which they were entitled; but to use the language of a sound observer, "*Nature fortunately remains more stable than prejudice*[2]," and few indeed are those

[1] It was this very intermixture of rocks having an igneous aspect with others which had been clearly formed under the sea, which led to those disputes about aqueous and igneous origin that now appear so trivial; the advocates of the Neptunian theory contending that all trap rocks were precipitates formed under water, because when compared with lavas they were found to be more compact! Yet, as Mr. Lyell has well observed, "The terms of comparison were imperfect, for one set of rocks formed almost entirely under water was contrasted with another which had cooled under the open air." (Principles of Geology, vol. iv. p. 353.)

[2] Bakewell, Travels in the Tarentaise, Alps Auvergne, vol. ii. p. 295.

who now venture to dissent from the doctrines of the Scottish philosophers. No individual has more advanced this branch of the science than Macculloch: few minutiæ of chemical combination, lithological structure, or mechanical effect escaped him; and to the accuracy as well as to the number of his observations, we are indebted for many of the most satisfactory proofs of the volcanic nature of the class of rocks under consideration. In short, he well remarks: "It is a mere dispute about terms to refuse to the ancient eruptions of trap the name of submarine volcanos, for they are such in every essential point, although they no longer eject fire and smoke[1]." Following up this train of research, the same author further proved, that granite was but one term in the series of igneous products, tracing with scrupulous accuracy the passages from what was formerly called *primitive* granite, to granitoid syenite, and syenitic greenstone, and thence into greenstone, basalt, and lava[2].

Such is a mere outline of the grounds upon which geologists have arrived at the conclusion, that trap rocks are of volcanic origin. In the course of this work, examples will be first adduced of phenomena illustrative of the relations of intrusive trap; or of volcanic matter which has burst in irregular forms through *sediment previously deposited*; and pursuing the inquiry in subsequent chapters, it will be shown, that the greatest fractures of these deposits have taken place on lines of volcanic eruption, or upon such as are parallel to them, usually accompanied by considerable changes in the condition of the strata thus penetrated. There is, however, another and a very ancient class of

1 System of Geology, vol. ii. page 114. See also this author's beautiful and instructive work on the Western Highlands, with plates. Classification of rocks, &c.

2 Having alluded to the school of Scottish geologists, I have much pleasure in recording my sense of the eminent services of Professor Jameson in classifying the trap rocks of his country. Imbued in early life with the tenets of Werner, his first views, like those of all the pupils of that master, were necessarily opposed to those here advocated; but we must not forget that the opposing arguments of this skilful mineralogist led to many of those discussions which have at length freed the subject of its obscurities; whilst it is most creditable to the candour and philosophic spirit of Professor Jameson, that being once convinced of the igneous origin of trap, he joined issue with his former opponents, and has now become one of the most efficient expounders of that theory.

Dr. Ami Boué (whose indefatigable research has led him at this moment into the Servian and Turkish mountains,) will always occupy a place in the memory of British geologists, for having at an early period applied his powers to describe the mineral structure of Scotland, and to endeavour to class its trap rocks (*Essai Géologique sur l'Ecosse*). Nor can we forget that Necker de Saussure was educated in the same school, and by a work of his youth (*Voyage en Ecosse et aux Iles Hebrides*) gave earnest of one day maturing into the author of the *Règne Mineral*, (Geneva, 1836). With these brief allusions to what may be termed the history of British trap rocks, I ought perhaps to advert no further to foreign writers who have enlightened us by their views, but my vivid recollection of the energy and talent displayed by the Prussian geologists Oeynhausen and Dechen in describing many of our insular igneous products, impels me to say that the comparisons drawn by them between these and rocks of similar structure on the Continent are striking proofs of the value of such international visits. (See Karsten's *Archiv*; *Inseln Skye*, and other works). MM. Elie de Beaumont and Dufrénoy likewise having made themselves perfectly conversant with our rocks, have drawn excellent and illustrative parallels.

trap rocks, which has been little adverted to by writers, and upon which I shall endeavour to throw some new light. These are the rocks named in the following chapters "Volcanic grit," "Bedded and contemporaneous trap," and which I undertake to prove were formed at the bottom of the sea *during* the accumulation of the sedimentary matter with which they are associated, particularly in the lower strata of the Silurian System. At one place these appear as currents or sheets of pure volcanic materials, at another they envelope marine remains, pebbles, sand, and fragments of rocks. Some layers consist of finely levigated volcanic scoriæ passing into sand; and all these varieties alternate so equally and repeatedly with beds composed exclusively of shelly and marine sediments, that no doubt can be entertained that the diversified masses so arranged in parallel strata, must have been formed *during* the same period of igneous action. In the remote æra therefore of the Silurian System, the evidences of volcanic operations are similar to those which Mr. Lyell has noticed in the modern deposits of Sicily, where banks of existing species of marine shells, now at considerable heights above the sea, are so *interlaced* with volcanic matter, that no other deduction can be permitted, than that the whole of these masses were of contemporaneous submarine formation. "We are therefore," adds that Author, "entitled to expect, that if we could obtain access to the existing bed of the ocean, and explore the igneous rocks poured out within the last 5000 years, beneath the pressure of a sea of immense depth, we should behold formations of modern date very similar to the most ancient trap rocks of our island[1]."

In pointing out an analogy to existing nature in the bedded trap of a very ancient geological period, we also fix the chronology of one class of igneous rocks;—for those of intrusive character so predominant in these islands, are rarely capable of such a limitation. We have often heard, indeed, of "coal measure trap," and "greywacke trap," as if such rocks were formed *during* the carboniferous or greywacke periods, whilst in the great majority of examples nothing is further from the truth. For instance, it will presently be shown, that basalt has penetrated and overflowed coal-fields, dislocating and fracturing the strata, and therefore we know it must have been erupted subsequently to their consolidation: but as the carbonaceous strata so affected are not covered immediately by any newer deposit, at what period were they so penetrated? Examples, indeed, will be given, from which it may be fairly inferred, that the coal-bearing strata have been forced up through once overlying red sandstone, and therefore that some of the volcanic agents which disturbed these coal-fields were in action subsequently to the æra of the New Red System. In the same manner trap will be shown to have penetrated new red sandstone, and reasons will be given for legitimately concluding, that such eruption took place after the completion of the New Red System, and even probably of the Lias.

[1] Principles of Geology, 4th edition, vol. iv. p. 254.

But if analogous proofs of this nature be sought from other parts of the island, the great basaltic dyke which ranges from a focus of volcanic action near the sources of the Tees, to Robin Hood's Bay on the coast of Yorkshire[1], intersecting all the formations from the lowest coal-measures to the inferior oolite inclusive, affords the best example of the *impossibility* of inferring the age of trap, from that of the sedimentary rock with which it is found in *intrusive* contact. The observer whose researches did not extend beyond the coal-measures, might assign the date of irruption to that formation; while another examining the Yorkshire coast would prove that it was of an age posterior to the oolites. Lastly, as if tending to exclude all limitation, the North of Ireland tells us that basaltic and other trap rocks, even including syenite[2], have been erupted through chalk, the very youngest of our secondary formations! Where then, we may ask, can the geologist arrest his steps in deciding upon the age of many of these masses of eruptive trap? How can he venture to assert, that the very basalt which has flowed over the coal of the Clee Hills, or pierced the coal of Staffordshire, was not emitted after the accumulation of the most recent of our secondary rocks? or that some of these eruptions may not have accompanied those movements of elevation, by which even the youngest tertiary deposits of our island were raised from the bed of the ocean?

Whilst, therefore, it is always difficult, and often impracticable, to define the age of some of the intrusive trap rocks, the more gratifying is it to retrace in other masses of the same class formed anterior to the accumulation of the Old Red and Carboniferous Systems, the clearest proofs of intermittent and repeated volcanic emissions; for, although they have been poured out in a period of high antiquity, we are still able to read off in them distinct analogies to Nature's present operations. The types of the Silurian System and the associated volcanic rocks have remained so clear, that the geologist has in them a record never to be mistaken,—one which will enable him to descend from their horizon into those deeper-seated rocks, amid which Professor Sedgwick has detected analogous relations; showing that in Cumberland and Wales there are numberless bands of porphyry, interstratified with, and participating in all the flexures of the slates, the whole of which have been subsequently pierced through by other and intrusive masses of igneous origin. But although in these regions, the volcanic operations have been upon a grander scale than in the Silurian country, there is not (I speak on the authority of my friend), that clear demarcation between the products of fire and of water, to which I shall in subsequent chapters direct attention, the whole mass of rocks being generally crystalline and altered (metamorphic), and very rarely presenting any traces of organic remains. And hence these regions are ill fitted

[1] See an excellent account of this basaltic dyke and the associated phenomena by Professor Sedgwick, Trans. Phil. Soc. Cambridge, vol. ii. p. 139.

[2] Mr. Griffith discovered this phenomenon and announced it to the British Association at Dublin, 1835. Subsequently Professor Sedgwick and myself visited the locality in company with Mr. G. See Geol. Proc., Phil. Mag., vol. viii. N.S., p. 559.

for elementary study, as it requires long practice to decipher correctly such dark pages in the history of the earth.

To the phenomena, however, illustrating the stratified trap rocks of the Silurian System, the reader will not be invited for some time, as he must previously accompany me in descending order through many overlying deposits, till we reach the older Silurian rocks, occupying the western part of Shropshire and adjacent parts of Montgomeryshire, as well as large portions of Radnorshire ; districts which, (as far as my knowledge goes) are unrivalled in the British Isles, for the number and clearness of the illustrations bearing on this interesting point of inquiry. Let not my reader imagine, it is here asserted, that contemporaneous and bedded trap rocks, similar in kind to those of the Silurian System, do not sometimes exist in overlying formations ; reasons, indeed, will hereafter be adduced which favour the belief, that even in a part of the region under consideration, rocks of this character have been elaborated during the carboniferous æra, though not in the same striking manner as in the Lower Silurian epoch. The "trap tufs" of Hales Owen, hereafter to be described, must either belong to this class, or be considered as regenerated deposits, the trappean ingredients having been derived from preexisting and solidified masses of rock. This ambiguous point will be fully considered in the chapter on the Dudley coal-field. But in other parts of the kingdom the secondary formations afford proofs of these phenomena. Thus, in Devonshire, Mr. De la Beche has recently observed the existence of trap, which from its relations, he conceives must have been ejected during the formation of the lower members of the New Red Sandstone of that district[1]. Again, in the North of England, Mr. Hutton has attempted to show, that the eruption of a large portion of the whin-sill or basalt of Northumberland and Durham was coeval with the carboniferous epoch, whilst another portion of it has been demonstrated by Professor Sedgwick to be of comparatively recent date[2]. Such examples are quite in accordance with natural laws ; and as our field of observation extends, there can be little doubt, that the phenomena of bedded and contemporaneous trap rocks will hereafter be recognised in many deposits of different ages.

As this work professes to describe geological phenomena in descending order, or in other words from the more recent to the more ancient, it might be expected that this general view of their origin, would be immediately followed by a description of the trap

[1] Geol. Proc., Phil. Mag., vol. vii. N.S. p. 513.

[2] Hutton on the stratiform basalt associated with the carboniferous formation of the North of England, Trans. Nat. Hist. Soc. of Northumberland, &c., vol. ii. p. 187.

Having examined a part only of the country described by Mr. Hutton, I cannot pretend to oppose my opinion to that of one who has so ably explored the whole of it; but as far as I saw them, the phenomena in the valley of the Tees (High Force, &c.) appeared to me to support the views which Professor Sedgwick had previously drawn from an examination of *that* portion of the tract in question. On this point, however, Professor Phillips justly observes, "It is not necessary to suppose that only one submarine flow of basalt occurred, any more than to confine it to one opening." Geology of Yorkshire, vol. ii. p. 85.

rocks which in the map and sectional illustrations appear in immediate relation to strata already described (the New Red System). I am, however, acquainted with one example only in this region, where trap can be *seen* to have been intruded into the New Red Sandstone; and this intrusion having taken place on a line of ancient volcanic eruption, the origin of which cannot be understood without a previous acquaintance with the history of the Silurian System, the account of this new red trap dyke is necessarily deferred to a subsequent chapter. In like manner, I postpone the consideration of those peculiar trap rocks, which rising to the surface in the Abberley and Clent Hills and adjacent tracts, frequently separate the New Red Sandstone from the coal-measures, for their relation cannot be comprehended until the carboniferous strata with which they are associated have been described. This class of trap rocks, though evidently of intrusive characters, yet carries with it unequivocal proofs of the period of its emission, and is, therefore, a marked exception to the eruptive rocks previously alluded to, the age of which is not bounded by clear geological limits; for, as already briefly hinted at, the syenites, porphyries, or other felspathic rocks of which these hills are composed, were manifestly erupted before the accumulation of the greater portion of the New Red Sandstone, since fragments of them occur abundantly in conglomerates near the lower part of that system. On the other hand, as some of the adjacent carboniferous strata are shattered and highly dislocated, ample proof is afforded, that these trap rocks must have been thrown up, either towards the close of the carboniferous æra or during the earliest period of the New Red System; and thus we have a right to affirm that the epoch of their eruption is fixed[1].

After this digression explanatory of the rocks of igneous origin, we may again proceed to consider the stratified deposits in their regular sequence, commencing with the upper surface of the carboniferous series, at which we had already arrived in descending order; simply premising, that after the explanation here given, the description of trap rocks, wherever they occur, will, in each succeeding chapter, follow the account of the sedimentary deposits with which they are associated.

[1] The reader will better understand the object of this chapter after consulting the small coloured sections II. and III. which are placed upon the margin of the map.

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The opposite sketch is taken from the upper part of Hagley Park, the seat of Lord Lyttelton, placed on the north-western slope of the Clent Hills, one of the trappean ridges alluded to in the text; the Malvern Hills, which are also of the same class, appearing in the distance. The Abberley Hills, or northern prolongation of the Malverns, are seen from the same spot, but can be included only in a panoramic drawing. The low country or plain of Worcester is occupied by the New Red Sandstone described in the previous chapters. I am indebted to Mrs. T. Phillips for this beautiful drawing.

# CHAPTER VI.

## CARBONIFEROUS SYSTEM.

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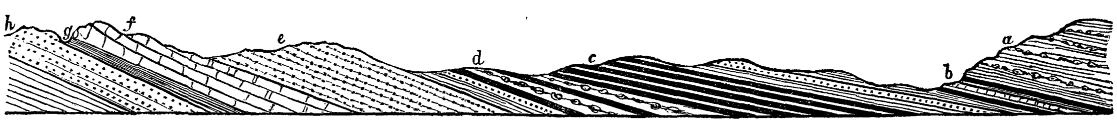
### *Introduction—Upper Coal Measures and Freshwater Limestone.*

*Introduction.*

MY chief object in this and the next six chapters, is to convey a clear idea of the pro minent relations of the carboniferous strata to the overlying and underlying systems, and to furnish means of comparing these rocks in the region under examination with those of similar age in other parts of Great Britain. Following up the inquiry commenced towards the end of the fourth chapter, I would first direct attention to those tracts, where there are evidences of a passage downwards from the Lower New Red Sandstone into the carboniferous strata. It will afterwards be shown, that the underlying formations of millstone grit and carboniferous or mountain limestone, are unproductive of coal; and lastly it will appear, that the carboniferous limestone graduates downwards into the Old Red Sandstone with as much regularity as the Lower New Red Sandstone passes down into the upper coal measures. These general views are explained in this wood-cut.

10.




*a.* Lower New Red Sandstone, with calcareous concretions described in the last chapter.
*b.* Upper coal measures with freshwater limestone.
*c.* Main coal.
*d.* Lower coal and ironstone.
*e.* Millstone grit.
*f.* and *g.* Carboniferous limestone and shale.
*h.* Conglomerate and sandstone, or upper formation of the Old Red System.

The various coal-fields will be described in the following order.

1. *Shrewsbury.* The carboniferous strata around Shrewsbury will be shown to consist of a younger or upper zone, which immediately succeeding to the Lower New Red Sandstone, contains within it a limestone of freshwater or estuary origin, peculiar to the coal-fields of the central counties of England.

*Coal Brook Dale.* The account of this, the most productive of the Shropshire coal-fields, will naturally follow, to show, that the thin or upper coal measures of Shrewsbury, reappearing in this tract, are underlaid by lower and thicker carbonaceous masses, containing many beds of valuable coal. Descriptions of the other detached coal-fields of Shropshire will then be given in the following order. *The Clee Hills; The Forest of Wyre, or Bewdley,* and *Oswestry.*

Quitting the Salopian fields, and passing to the south, the small district of *Newent*, in Gloucestershire, will claim a brief notice; but the important coal basin of the *Forest of Dean* will not occupy attention further than by occasional references, since it has been adequately illustrated by Messrs. Buckland and Conybeare, aided by the local knowledge of Mr. Mushett[1].

*South-Welsh Coal-field,* (Glamorgan, Monmouth, Brecon and Caermarthen). No detailed account will be given of any part of this valuable and rich basin, which has been long under the examination of the Rev. W. Conybeare, for whose memoir every geologist is looking with impatience; but the boundaries of this tract will be alluded to, their eastern, northern and western outlines having been accurately laid down on the map, to indicate the great disruptions along the margin of the basin, and to show the vast expansion of the carboniferous limestone between the South Welsh and Bristol coal-fields.

We shall then proceed to the consideration of the Old Red Sandstone and Silurian rocks; the description of the coal-fields of *Pembroke* and *Dudley* being deferred to future chapters, as the carboniferous strata in these tracts are so intimately connected with the older rocks, that the history of the one would be unintelligible without a previous acquaintance with the other. In this manner, after a regular examination of the whole succession of rocks, the complicated tracts of Pembrokeshire and Dudley, in which so many different members of the series are intermixed, will be the more easily explained; clear comparisons being established between them, and unequivocal strata in other parts. Thus carrying down our observations in descending order, the reader will be first familiarized with the nature of those coal-fields, which, although they have hitherto met with little attention, are not only of geological, but also of national interest; for as they are overlaid by the New Red Sandstone, so they may hereafter be worked from beneath that system in several of the central counties.

But besides the regularly stratified deposits of shale, coal, sandstone, grit, and limestone, of which they are composed, some of these coal-fields are perforated by trap

[1] The outlines of this remarkable coal basin, so symmetrically surrounded by zones of millstone grit, carboniferous limestone, and Old Red Sandstone, will be seen by reference to that part of the map which has been coloured from the original work of Mr. Maclauchlan, of the Ordnance Survey, now deposited in the collection of the Geological Society. I am indebted to this gentleman for much valuable information concerning this and other adjacent tracts, and particularly in the delineation of the outline of a large portion of the South Welsh coal-field, with the topography and geological structure of which he is most intimately acquainted.

rocks, which, as before stated, will be described towards the end of each chapter to complete the geological survey of the tracts in which they are found.

I have further endeavoured to explain the probable *origin* of the central coal-fields, by observations scattered through the sixth, seventh, and tenth chapters, and particularly at the conclusion of the eleventh chapter, in which we take leave of the carboniferous tracts of Shropshire.

1. *Upper Coal Measures and Freshwater Limestone.* (*b.* of wood-cut, p. 67.)

By inspecting the map it will be seen, that the ancient rocks which compose the Silurian and Cambrian Systems, ranging from Pembrokeshire on the south-west, terminate on the north-east in a succession of promontories, more or less parallel, and of unequal lengths, which form the southern, western, and eastern limits of the plain of Shrewsbury. These promontories are fringed by a narrow, broken, and devious zone of coal measures, extending from the Breidden Hills on the west, to the Wrekin on the east, the base line or lower edge of which, is determined by the headlands and bays of the ancient rocks. Sometimes, indeed, the carboniferous strata are so completely isolated by these protruding inferior masses, that they consist rather of a number of patches than of a continuous band. By this disposition, the coal measures repose unconformably and successively, upon rocks of various ages, from the flanks of which they dip away; and where not obscured by overlying drifted materials, they are seen to graduate upwards into the Lower New Red Sandstone, passing at slight angles of inclination beneath that formation. (Pl. 29. Figs. 3, 4, 5, 7 and 9.) The surface of a large portion of the plain of Shrewsbury is represented in the annexed view, the various ridges in the distance being composed of Cambrian, Silurian and Trappean rocks. The low country consists of New Red Sandstone and coal measures, for the most part overspread by a great thickness of gravel and detritus. Let us first examine the portion of this tract which is productive of coal, and lies between the north-eastern termination of the Breidden Hills and Shrewsbury. The principal outcrop of the coal is in a semicircular bay, of which Shrewsbury and Coedway are the eastern and western extremities, and the intermediate places where it has been worked, are Nobold, Wellbatch, Aston, Pontesbury, Minsterly, Westbury, Woolaston and Braggington; at most of which places the strata have only a slight inclination towards a common centre. It has already been stated, that the lowest strata of the overlying red sandstone at certain points in this district are in contact with, and in some instances graduate into the coal measures. This passage is seen at Wellbatch, Asterley, and Coedway. In these situations the coal measures rest on one side against ridges of older rocks, and on the other, dip in perfect conformity beneath the Lower New Red Sandstone. (See Pl. 29. fig. 5.) From the arrangement of these beds, as seen near Nobold, where the New Red Sandstone dips to the north-west, conformably with the inclination of the coal beds,

no geologist could doubt, that the red rock immediately overlies the carboniferous strata; and this conclusion has recently been established by sinkings, which having passed through variegated shale of the Lower New Red Sandstone containing impressions of plants, reached coal-bearing measures[1]. At Coedway, west of Alberbury, the opposite extremity of the trough, the coal strata dip to the north-east, again passing beneath red shale and sandstone, but the seams are of little value and have not been followed upon the dip. (Pl. 29. fig. 9.) In most other portions of this trough there is no possibility of observing the precise relations of the coal measures to the overlying strata, owing to an enormous accumulation of coarse detritus which overspreads the country. The following account, therefore, of this tract is derived from observations made at points where the coal has been worked along the tortuous line above indicated, and also in the several bays and recesses of the older rocks to the south-east of Shrewsbury. (See Map and view.)

Where most developed, this formation contains three seams of coal, which, in descending order, consist of *half-yard*, *yard*, and *two-foot* coals. The quality, thickness, and even the number of these beds vary in different places, but it may be stated as a general rule, that the lowest or two-foot coal is the best, the middle and upper seams being for the most part pyritous and of inferior quality, particularly the yard coal, usually termed "Stinkers." These coal beds are separated from each other by red, green, and black shale, and clod, some portions of which have a saponaceous feel, as if charged with magnesia, and thus they bear some resemblance to the variegated shale or marl of the overlying New Red System. The intervening argillaceous beds, containing occasionally a bed of sandstone, are of unequal thickness in distant parts of the trough, but at Pontesbury they amount to about fifty yards. Owing to the unequal thicknesses of the overlying strata, and also to numerous dislocations, the coal seams are necessarily reached at various levels, the depths of the shafts increasing with the distance from the natural outcrop of the coal. The deepest pits, or those furthest from the edge of the field, are about ninety-five yards, whilst the shallowest or those nearest to the hilly sides of the older rocks are not more than ten or twenty. Wherever the measures have been examined between Pontesbury and Westbury, the three beds of coal have been found; but to the westward of the latter place one of them appears to thin out. There is, however, a considerable space along which no trials have been made, and the old works at Woolaston have been so long abandoned, that no correct information is to be obtained respecting them. At Braggington and Coedway, the western termination of the field, there are only two beds of coal worth working, the

[1] The trials alluded to were made by Mr. Hughes of Wellbatch, and the fragments of plants in the variegated shale were recognised by Professor Lindley as being similar to those found in other coal-fields; but unfortunately the specimens have been mislaid, and I am now unable to state their specific names. (See an account of plants found in red shale or marl above the coal measures of this age at Ardwick, near Manchester, p. 88, note 1.)

lowest of these, or the thin coal, being from about fifteen to eighteen inches thick. The works at both these places are abandoned, those at Coedway having been wrought during a period of twenty years. At Braggington a good deal of capital was recently expended, but the thinness of the beds, their dislocations and high inclination, (close to the edge of the trappean rocks of the Breidden Hills,) and their distance from any good market, led to their abandonment. It appears, however, that the works were conducted in an unscientific manner; for there can be no doubt, that these beds of coal, though thin, might, if well managed, prove of considerable use in this district in burning the contiguous limestone of the dolomitic conglomerate. (Pl. 29. fig. 9.) The present success of the pits at Westbury is indeed a proof of how much may be done by spirit and assiduity.

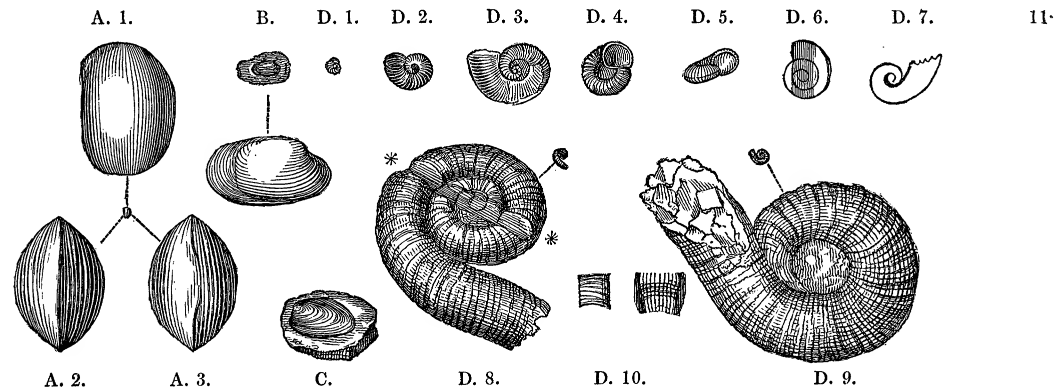
"*Freshwater Limestone.*"

The most remarkable feature in this coal-field, and one quite new to geologists when I announced the discovery, is a band of limestone, varying in thickness from three to eight feet, which lies *between* the seams of coal. The following shaft section of the strata at Pontesford shows its exact position, and explains the nature of the associated beds in a part of the coal-field where they are perhaps most developed.

| | ft. | in. |
|---|---|---|
| *a.* Gravel and detritus, thickness variable. | | |
| *b.* Various overlying strata of variegated shale, sandstone, clods, &c., with traces of lime and ironstone. These are the beds of transition or passage from the Lower New Red Sandstone. (See better detail of these beds at Wellbatch, p. 91.) | 90 | 0 |
| *c.* 1*st* or *half-yard Coal,* of good quality in some places near the outcrop, but generally more pyritous and sulphureous on the dip | 1 | 6 |
| *d. Poundstone and Crundall,* i. e. variegated sandy shale, with traces of coal plants | 6 | 0 |
| *e. Sandstone,* in beds of from three to four feet; a good building-stone | 27 | 0 |
| *f. Reds,* (stiff shale) | 6 | 0 |
| *g. White Clumpitty* (whitish shale) | 12 | 0 |
| *h. Lower Reds* (mixed shale) | 6 | 0 |
| *i.* LIMESTONE, in two beds, the lower one adhering tenaciously to underlying sandstone | 7 | 0 |
| *j. White Rowl,* yellowish white sandstone, with clods (clumpitty), &c. | 33 | 0 |
| *k. Mush,* a coal smut of varying thickness | 3 | 0 |
| *l. Black Clods,* or finely laminated coal shale, with abundance of impressions of plants | 6 | 0 |
| *m. 2nd, or Yard Coal,* usually termed "Stinkers", being highly pyritous and impure | 3 | 0 |
| *n. Clods, &c.* as above, with a few thin laminæ of coal and *smut* | 54 | 0 |
| *o. 3rd, or Thin Coal,* the hardest and purest coal in the shaft | 1 | 4 |
| | 255 | 10 |

The limestone, as appears by this section, is here about seven feet thick, and is divided into two beds, the uppermost of which is a compact cream-coloured rock, slightly argillaceous, with a splintery conchoidal fracture and dull lustre. The lower, though essentially the same limestone, is cellular, the cavities being filled with crystallized carbonate of lime and black bitumen, both viscous and compact, and veins of calcareous spar and sulphuret of iron are also disseminated through it. On the first examination

of this rock, I was struck with its strong resemblance to certain "lacustrine" limestones of France and Germany, which by their imbedded organic remains are known to have been formed under fresh water; and when I further discovered in 1832, that nearly all the fossil remains in the limestone or the associated strata, might be referred to terrestrial and fluviatile origin, one only being doubtful, I named it a "freshwater limestone." (See Geol. Proceedings, Phil. Mag., N.S. vol. iii. p. 225.) I traced this calcareous band at intervals from Nobold, near Shrewsbury, to Asterley beyond Pontesbury, *always occupying the same place between the first and second coals*, and varying very slightly in mineral characters. At Westbury it thins out, but at Braggington, near the western termination of the field, it reappears in a bed of about three feet thick. The characteristic fossil of the limestone is a very minute discoid univalve, resembling on first inspection *Planorbis Nautilus*, Fleming, and with this is associated a small bivalve having the form of a *Cyclas*, and also a small *Cypris*. In addition to the above-named fossils, the remains of fishes have been discovered, the most remarkable of which is a new species of the genus *Ctenodus* of Agassiz, named by that author *Ctenodus Murchisonii*[1]. Another fragment of a fish subsequently found in the shale above the limestone by Professor Phillips, proves to belong to *Megalichthys Hibberti*. I here insert a wood-cut illustrating the unpublished shells which are most characteristic of this limestone in Shropshire.




A. *Cypris inflata*. A. 1. A. 2. and A. 3. are magnified about twelve times.

This Cypris is obovate, smooth, and very much inflated: in the latter character it differs especially from all other known fossil species.

B. Two representations of a transversely elongated, rather compressed shell, resembling a *Cyclas*: one of them is magnified.

C. A shell resembling *Modiola* from Ardwick near Manchester. This shell has not been observed in Shropshire.

D. *Microconchus carbonarius*. It is thus named until its characters are better understood; it does not appear to be chambered. D. 2. to D. 7. are slightly magnified figures. D. 8. and D. 9. are highly magnified; over each of these, and at D. 1. are representations of the natural size. D. 10. refers to two figures of the striated surface. D. 8. at * * shows the impression of the substance to which the shell has been attached. See further description by Professor Phillips, p. 88. In examining this shell Mr. Lonsdale perceived that it was probably the same as the minute shell figured among Martin's *Petrificata Derbiensia* as *Conchyliolithus Helicites* (*pusillus*, pl. 25.), and which is stated to be of rare occurrence in *coal shale* at Chesterfield.

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[1] The fossil fish named *Ctenodus Murchisonii* by M. Agassiz was presented to me by the very Rev. Archdeacon Waties Corbett: a figure of this fossil may be seen in the Zoological Journal, vol. i. Pl. 8. p. 252.

The fossil plants which are found in the beds of shale of the Shrewsbury coal measures, and which occur in the largest quantities, are,

| Shrewsbury Coal-field. | Other Localities. |
| --- | --- |
| *Cyperites bicarinata*. Lindley and Hutton, Foss. Flor. vol. 1. pl. 43. fig. 1 and 2.<br>This remarkable plant, and several others of the Shrewsbury coal-field, were sent from Le Botwood to Dr. Buckland when I was examining the district, and being communicated by him to Professor Lindley, were figured in the Fossil Flora. I found numerous duplicates. According to Professor Lindley this plant is the first published evidence of the existence of Glumaceous Monocotyledons in the coal measures, and he named it *Cyperites*, rather from inability to match it with the leaves of any other family, than from any conviction that it really belongs to *Cyperaceæ*. | This species with several well-known and common coal plants has recently been found in the culm-bearing strata of Devonshire, which Professor Sedgwick and myself are convinced belong to the true carboniferous æra, and not to the grauwacke rocks as supposed by former authors. See Proceedings of British Association, 1836, and Anniversary Discourse of the President of the Geological Society, Feb. 1837. |
| *Lepidophyllum intermedium*. Foss. Flor. pl. 43. fig. 3. Supposed to belong to a plant allied to the coniferous genus *Podocarpus*. | This leaf is intermediate between the *Lepidophyllum lanceolatum* and *L. majus* of the Newcastle coal-field. |
| *Lepidostrobus variabilis*. Foss. Flor. vol. 1. pl. 11. Considered by M. Ad. Brongniart to be an organ of fructification belonging to *Lepidodendron*, and to be a reproductive body analogous to those of recent *Coniferæ* and *Lycopodiaceæ*. Foss. Flor. pl. 43. fig. 3. | Jarrow Colliery, Newcastle-on-Tyne. |
| *Lycopodites*. Sternberg, Flor. der Vorw. pl. 17. fig. 3. | Bohemian coal-fields. |
| *Leaf of a large Monocotyledonous plant.* | The same species occurs in the Lancashire coal-field, and particularly in the upper coal measures at Ardwick. |
| *Neuropteris cordata*. Brongn. Hist. des Végétaux fossiles, p. 229. t. 64. f. 5. Foss. Flor. pl. 41. | St. Etienne and Alais in France. It is also found in the culm-bearing strata of Devonshire. |
| *Neuropteris gigantea*? Fragments of. Foss. Flor. pl. 52. Ad. Brong. pl. 69. (*Osmunda gigantea*, Sternberg, tab. 22. *Filicites linguarius*, Schloth.) | Common to all the European coal-fields, also to the culm strata of Devon. |
| *Odontopteris obtusa*. Foss. Flor. pl. 40. A new genus so named by Professor Lindley from a Le Botwood specimen. (Occurs in other Salopian coal-fields.) | Terrasson in France. |
| *Pecopteris abbreviata*. Ad. Brong. Hist. des Végétaux foss. pl. 115. f. 1 and 4. | Near Bath in England, Anzin near Valenciennes in France. |
| *Pecopteris lonchitica*. Foss. Flor. vol. 2. pl. 153. *P. blechnoides*, Ad. Brongn.<br>This plant is also most abundant in the other Salopian coal-fields of Coalbrook Dale, Clee Hills, &c. (See wood-cut in the next chapter.) | Common to all the European coal-fields; figured by Sternberg from those of Bohemia and Silesia, and by Brongniart from those of France. In England it occurs in the Northumberland, Durham, Bristol and South Welsh coal-fields. It is also one of the most abundant plants in the culm strata of Devonshire. In Devon this species of *Pecopteris* is further associated with *Cyperites bicarinata, Neuropteris cordata, N. gigantea*, of the Shrewsbury coal-field, *Poacites cocoina* of the Coalbrook Dale, and Lancashire coal-fields, *Asterophyllites foliosa* of the Newcastle, *Calamites undulatus* of the Yorkshire and Bohemian coal-fields, and *Pecopteris muricata*, Brongn., from Valenciennes. |

Reverting to the consideration of the band of limestone above described, I may state, that the geological interest attached to it has been much enhanced, by finding it in various other localities near Shrewsbury, such as Nobold, Uffington, Le Botwood, &c., occupying the same geological position, and interstratified with the same plant-bearing shales, and seams of coal, and also by observing it, 1832, on the southern edge of the great coal-field of Coalbrook Dale, where it has since been shown by Mr. J. Prestwich to overlie the lower or rich coal-field of that tract, thus completely proving the zone of coal measures in which the limestone occurs, to be *the youngest* member of the carboniferous system, an inference indeed which I had deduced from many examples of transition between it and the Lower New Red Sandstone.

Upwards of three years after I had communicated my views concerning the freshwater limestone, to the Geological Society of London, certain carboniferous rocks at Ardwick near Manchester were described by Mr. W. C. Williamson, with notices of numerous fossils which he had collected, (Phil. Mag., Oct. 1836). From the silence of this author concerning my observations in Shropshire, it would appear he had been unacquainted with them, and had therefore no suspicion that the calcareous rocks he was describing, bore any affinity to this peculiar coal measure limestone. Professor Phillips having visited Manchester when the Ardwick limestone was under examination, was furnished by Dr. C. Phillips and Mr. Mellor with a complete general section of these beds. He at once detected the little microscopic shell so abundant in that limestone, and recognised it as identical with the planorboid shell of the Shrewsbury rock; and following up his inquiries, he perceived other analogies of the organic remains, which had previously escaped notice. By these researches, and by examination of the strata, it became manifest to him, that Dr. C. Phillips had rightly associated these limestones and red marls with the coal formation, and that the fossiliferous and calcareous coal measures of Ardwick near Manchester, were of precisely the same age as those I had described near Shrewsbury. But other zoological interest was attached to this limestone; for as, in its extension to Manchester, it was found to be of greater thickness, so it also proved to be richer in organic remains than in Shropshire. Collecting a number of individuals of the little planorboid shell, Professor Phillips made magnified drawings of them, with which he kindly furnished me for the illustration of this work, and from which some of the figures in the preceding wood-cut have been taken and prepared by Mr. J. Sowerby. To make the reader fully acquainted with all the contents of this limestone in Lancashire, where it is so much developed, I annex in the following page a description from the pen of Professor Phillips of the organic remains it contains at Manchester, as extracted from a letter to myself. In the mean time the following is a summary of the strata in which they are imbedded, constructed from the original sections of Dr. C. Phillips and Mr. Mellor, the memoir of Mr. Williamson, and the personal investigation of Professor Phillips.

| | ft. | in. | |
|---|---|---|---|
| New Red Sandstone and variegated marls (*unconformable to the strata below*) | | | New Red System. Transition to coal. |
| LIMESTONE | 4 | 0 | |
| Red and green argillaceous shelly marls | 15 | 0 | |
| LIMESTONE | 3 | 0 | |
| Red and green marls | 24 | 0 | |
| LIMESTONE (occasional) | 1 | 0 | |
| Marls and shale[1], &c., with calcareous courses | 15 | 0 | |
| LIMESTONE | 1 | 6 | |
| Shale, &c. | 45 | 0 | |
| Coal and bass | 1 | 6 | |
| Sandy shale | 4 | 6 | Upper Coal Measures. |
| MAIN OR GREAT-MINE LIMESTONE | 9 | 0 | |
| Red marls with calcareous bands | 60 | 0 | |
| Coal | 1 | 4 | |
| Grit or great red rock, with micaceous marls and Uniones | 81 | 0 | |
| Coal | | 10 | |
| Clays and grits with iron stone | 216 | 0 | |
| Red laminated marls and thin grits | 150 | 0 | |
| Berwick red rock (finely laminated and micaceous) | 54 | 0 | |
| Shale | 12 | 0 | |
| Openshaw coal | 2 | 3 | |
| Aqueduct rock. | | | |

Below the aqueduct rock the descending section exhibits a great development of *red* grits, alternating with coal seams in the following order.

| | ft. | in. | |
|---|---|---|---|
| Coal | 0 | 10 | Coal Measures. |
| Rocks, &c. | 131 | 0 | |
| Fitzgerald's coal | 2 | 0 | |
| Rocks of grit, &c. | 210 | 0 | |
| Coal (three-quarter) | 2 | 3 | |
| Rocks | 57 | 0 | |
| Coal (Buckleys) | 4 | 0 | |
| Rocks | 120 | 0 | |
| Yard coal, shells and Cypris in roof | 3 | 0 | |
| Rocks, &c. | 60 | 0 | |
| Coal | 2 | 6 | |
| Rocks | 129 | 0 | |
| Doctor coal | 1 | 2 | |
| Rocks | 33 | 0 | |
| Coal | 2 | 0 | |
| Rocks | 126 | 0 | |
| Coal | 0 | 10 | |
| Rocks | 68 | 0 | |
| Coal | 0 | 8 | |

Average specimens of the great mine or upper coal limestone at Ardwick, and the adjacent magnesian limestone at Collyhurst, having, at the request of Professor Phillips, been analysed by Mr. H. C. Campbell, have given the following results[2].

| | Ardwick. | Collyhurst. |
|---|---|---|
| Carbonate of Lime | 84 | 60 |
| Carbonate of Magnesia | 2 | 9 |
| Alumina | 4 | 24 |
| Oxide of Iron | 5 | 4 |
| Loss | 5 | 3 |
| | 100 | 100 |

To Mr. Williamson's account of the Ardwick Limestone, Professor Phillips in the letter above alluded to adds the remark, that the sections at different spots give different results as to the number of beds of limestone;—thus, in one shaft at Ardwick the place of the four-foot lime of the above section is merely traceable, there being only three limestones above the main band; while in another pit, calcareous matter intervenes below the half-yard mine, at a depth at which in other works, the

[1] Most of the red and green marls, shale, &c., of this section are described by Mr. Williamson as "Clunch," the local term of the miners. Few of them, I believe, are, strictly speaking, marls. In a section drawn by Mr. Binney, and furnished me by Mr. Leigh, seven courses of limestone are marked.

[2] The chemical properties of the Ardwick limestone were thoroughly understood by the late celebrated and lamented Dr. Henry.

strata consist entirely of argillaceous marls or sandstone. This indeed is quite what the geologist would expect to find amid strata composed of such rapid alternations of marl, sandstone, grit, shale, and limestone. Professor Phillips also alludes to the occurrence of reddish masses of silex in the limestone, of which he says, "These will doubtless recall to your recollection several freshwater limestones on the Continent." He then proceeds to give the following explanation of the nature of the organic remains:

"The organic remains of this series are terrestrial, fluviatile, and of doubtful origin. The plants are all terrestrial, namely,

"*Asterophyllites*, one species; *Calamites*, two or three species (*C. nodosus*, according to Williamson); *Cyclopteris*, one species; *Lepidodendron*, one species (*L. Sternbergii* according to Williamson); *Neuropteris cordata* (Lindley and Hutton, Fossil Flora; same species at Le Botwood); *Pecopteris*, three species; *Stigmaria ficoides*. *Leaf of a monocotyledonous plant*, similar to one occurring at Le Botwood, Salop, with portions of other very narrow monocotyledonous leaves resembling *Nöggerathia foliosa*, some of which are brown, transparent, and elastic. These plants occur in the shale, bass, &c., alternating with the limestones[1].

"*Shells*. The most characteristic is a microscopic spiral shell of few volutions, which touch one another like *Planorbis* when young, but when old are extended into a free tube like *Vermetus* or rather like *Vermilia*. The shell is sinistral like *Planorbis*, but sometimes shows proof of being attached on one side like *Spirorbis*. Lines of growth, strong, somewhat irregular, deficient in parallelism, and oblique to the axis of the tube (D. 10.) as in *Planorbis*; faint spiral striæ, can just be seen. This shell, which I have identified with your Salopian planorboid shell, is also probably the same as a species I have seen from the coal measures of Fitzgerald's Colliery near Manchester, as well as from the lower part of the Yorkshire and Newcastle coal-fields." (See wood-cut, p. 84. The figures D. 1. to 10. represent this shell *Microconchus carbonarius*.)

"The only other distinct shell which I have obtained from the limestone looks so very like a young *Modiola* that I hesitate to call it *Unio*. (Wood-cut, p. 84. fig. *c*.) It is a tumid little shell, smooth, but with very distinct lines of growth, prominent beaks, and rather short straight hinge lines. In the argillaceous beds associated with the limestones are three species of *Unio*. The most common of these is nearly elliptical; the hinge line deviates considerably from parallelism to the front, and ends in a prominent angle; lines of growth strong, shell very thin, beaks slightly prominent. Mr. Williamson has inaccurately referred this shell to *Unio nuciformis*. It occurs in the red beds above the limestones, in the black bass, and in the underlying coal measures.

"The second species, which I named *U. linguiformis* (*U. Phillipsii* of Williamson), is transversely elongated, three times as wide as long; the hinge line deviates very little from parallelism to the front lines of growth; shell fine, very thin and smooth. This shell is found in the black bass. The third species, which I named *Unio rugulosus*, is of obliquely expanded or semi-elliptical form, the hinge line forming the diameter. Surface concentrically marked with broken undulations, often showing radiations on the posterior slopes; shell exceedingly thin. *Unionidæ* of the same

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[1] Mr. Williamson, in the interesting memoir before alluded to, states the important fact, that in the *red shale*, sixty feet above the main limestone, and therefore in the beds of transition between the Lower New Red and the coal measures, Mr. Mellor and himself discovered many impressions of plants, among which were *Calamites decoratus*, *C. nodosus*, *Lepidodendron Sternbergii*, *Neuropteris cordata*, *Stigmaria ficoides*, &c. These plants occur as nearly as possible in the position of the beds overlying the upper coal seam of the Shrewsbury field.

species occur in the beds of mottled marls *above* the limestones, in the black bass or shale above the main limestone, and in the shale beneath all the calcareous bands. Another bivalve found in the black bass above the limestone is probably a *Cyclas*, and a singular bivalvular body, found in the shale by Mr. Williamson, I would describe as most resembling *Aptychus*, being equivalved, with a straight hinge the breadth of the shell, the anterior side rounded, the posterior truncate, two diverging ridges from the beak, about twelve crenate furrows parallel to the margin, and all alike, colour fine brown, appearance like a fish scale, the inside nearly smooth. Of *Crustacea*, I found in the black bass one *Cypris*, having a very glossy shell of elliptical shape, and in prodigious abundance, mixed with fish scales. Another species of *Cypris* I discovered in the roof of the yard coal (see section, p. 87.), probably the same as one I formerly found in the lower coal strata near Halifax, and which also occurs in the coal-measures of the Tyne.

"Of vertebrated fossils the black bass contains abundance of fragments, chiefly belonging to *Palæoniscus Freieslebeni*? of the *Magnesian Limestone*, and another species with plain scales, such as occurs in foreign coal tracts. I also detected large scales of the beautiful large species of fish formerly found in the coal measures near Leeds, and which is deposited in the museum of that town, and I was still more gratified to detect in the main bed of limestone a considerable number of bones, which reminded me of reptile structure, together with portions of skin, continuous, beautifully striated, and shagreened. My impression, that these were portions of a reptile, was strengthened by finding large bones, possibly of the head, pitted and roughened very differently from the surface of the bones found at Burdie House near Edinburgh, and at Leeds. Mr. Mellor has since found a jaw with teeth very similar to *Holoptychus Hibberti* (Agass.). Mr. Francis Loomy discovered a tooth, probably of *Ctenodus*; and a splendid specimen of this genus *perfectly identical with the C. Murchisonii* (*Agass.*) *of Le Botwood*, has been placed in the Manchester Museum by Mr. Miller.

*The upper carbonaceous zone* of Lancashire is thus identified by mineral characters and by organic remains with the Shrewsbury coal-field, from which, however, it differs in exhibiting a much greater development of limestone; and with this increase of calcareous matter, we perceive a corresponding increase in the number and variety of the remains of animal life, particularly in the *testaceous Mollusca*, whose existence could not have been prolonged without an adequate supply of carbonate of lime. Similar analogies of increased numbers of fossil shells, where calcareous rocks prevail, will be pointed out in the course of this work in other strata of much higher antiquity. It is further highly interesting to observe in these rich fossiliferous beds of Manchester, the occurrence of the *Palæoniscus Freieslebeni?*, a fish eminently characteristic of the *Magnesian Limestone*, associated with some peculiar animal remains, and with many plants and other fossils common to the *ordinary coal measures*, an intermixture which affords zoological proofs, that the zone in question is made up of transition strata, connecting the New Red and Carboniferous Systems. At the same time, (if the species be correctly determined)[1], this discovery tends to modify one of the strongly defined stratigraphical characters assigned to fossil fishes by the researches of M. Agassiz; for whilst occasionally

[1] I have requested Professor Phillips to send the specimens to London, and the result of their examination will be announced in the Appendix.

some few species in other classes of the animal kingdom are known to have lived on through various successive periods, each species of ichthyolite is supposed by that author to be *peculiar* to the *formation* in which it is found imbedded. Now, in the preceding chapter, it has been shown, that the formation of the lower New Red Sandstone, having a maximum thickness of nearly one thousand feet, is interpolated between the magnesian limestone and the coal-measures, in both of which formations, thus widely separated, we now find *the same species* of fish. It has, however, been my object to show, that no violent interruption of the series of deposits of this age has occurred in Shropshire or Staffordshire; and hence we might well imagine, why under such conditions, animals of the same species should have continued to exist during a very long period. But at Manchester, the stratigraphical relations are different from those described in the central counties ; the red sandstone and marls, including the equivalent of the magnesian limestone before mentioned, being *un*conformable to the upper coal measures and freshwater limestone : yet notwithstanding this dislocation, which interrupts the perfect sequence of deposits, there is still a complete transition in mineral type and organic contents.

After this comparison of the most interesting features of the Shrewsbury and Manchester coal-fields, I will now revert to the detailed description of other phenomena in rocks of this age in Shropshire.

Although it has been stated that for the most part the strata in the Shrewsbury coal-field are seldom inclined more than five inches in a yard, as at Pontesbury, there are exceptions to this rule, particularly at the extreme end of the zone at Coed Way, where the coal dips at a high angle beneath the oldest members of the New Red Sandstone and Dolomitic Conglomerate. Among the numberless faults which affect the strata, the chief one at Pontesbury runs from north-north-east to south-south-west and is a downcast of seventeen yards on the dip, whereby the limestone is thrown down nearly to the level of the thin or lower coal. (Pl. 29. fig. 8.)

As this zone of the coal approaches Shrewsbury it becomes thinner and more disjointed. It is now worked at Ascot, and was in former times extracted at the Moat; a patch of it forms a broken and elevated trough extending to Longden, where the coal rises to within a few yards of the surface, but is not worked, and rests upon purple greywacke grits of the Cambrian system. The latter rock here advances from the Longmynd and Linley Hills into the narrow promontory of Lyth Hill, round which the narrow zone of coal-measures is folded, and occasionally rises, as at Longden, to some height. This purple greywacke is the irregular base on which this part of the coal-field rests, and hence the coal which occurs at one spot, in consequence of the older rocks lying at certain depths, is cut out at other points by the protrusion of these ancient formations. Along the western edge of this promontory the coal-measures as they advance towards Shrewsbury continue to be in a very broken condition. The upper coal is the only seam which has been found in this quarter, most of the old works at Wellbatch, the Moat, and Sutton having effected little more than clearing away the basset edges of the mineral as it rose up on the sides of the underlying Cambrian rock. Mr. Hughes of Wellbatch, however, has made, and is still occupied in making trials upon the dip of these beds by which the coal has recently been won beneath the Lower New Red Sandstone. Though

the shaft sections *vary considerably* in different parts of this tract, the following may be taken as one of the fullest exhibitions of the measures sunk through at Wellbatch.

| | | Yards. | ft. | in. |
|---|---|---|---|---|
| Portions of Lower New Red. | Reddish clay | 3 | 0 | 0 |
| | Sandstone of dull brownish red colour | 3 | 0 | 0 |
| | Red and green shale with fragments of plants | 20 | 0 | 0 |
| | Top rock (grey sandstone) | 3 | 0 | 0 |
| | Curdled poundstone (a mixture of sand, clay, containing plants) | 5 | 0 | 0 |
| | Kind clod (shale) | 4 | 0 | 0 |
| | Coal | 0 | 0 | 9 |
| | Poundstone | 1 | 0 | 0 |
| | Kind clod | 5 | 0 | 0 |
| | Coal | 0 | 0 | 1 |
| | Curdled poundstone | 1 | 0 | 0 |
| | Four-yard rock, a greenish-white hard sandstone | 4 | 0 | 0 |
| | Light-coloured poundstone | 1 | 0 | 0 |
| | Clod | 4 | 0 | 0 |
| | Coal | 0 | 0 | 1 |
| | Poundstone | 1 | 0 | 0 |
| | Clod | 7 | 0 | 0 |
| | Coal, the uppermost seam of the other sections | 0 | 1 | 8 |
| | Total | 62 | 2 | 7 |

In this spot the limestone is no longer worked, but it has been reached beneath the last-mentioned bed of coal, which is therefore proved to be the uppermost of the three seams before mentioned. In sinking to the limestone, the shafts passed through a course of small concretions of calcareous clay iron stone, called "Rattlers," in which I observed nests and coatings of mineral pitch and veins of white calcareous spar. This may represent one of the thin Manchester limestones. There being no natural denudations in this district it is only from an occasional trial shaft, like this, that I have had any opportunity of judging of the precise structure of the beds passed through, and it is therefore probable that in the section at Pontesbury (p. 83.) and in other parts of this coal-field, the overlying strata may contain other thin courses of impure concretionary limestone which have escaped the notice of the miners, and if so the analogy between the Shropshire and Lancashire beds may be still more complete, even to agreement in mineral characters. Neither of the lower coals have ever been proved at Ascot, the Moat, or at Wellbatch, though the limestone has been extracted to some extent at Nobold. This portion of the field is indeed exceedingly dislocated, it being difficult to find a spot exceeding a few yards in width, in which the strata are not full of faults. This is specially observable on the sides and slopes of Lyth Hill, the promontory of purple greywacke or Cambrian rock which has been alluded to, and which, as we shall show, is penetrated in many points by trap rocks. Between Lythwood and the brook at Wellbatch, a distance not exceeding half a mile, there are four principal upcasts upon the dip of the strata, the greatest of which is a rise of forty, the least of about eight yards. It is to be remarked, that, here the beds are inclined to the north-west,

sloping away from the Lyth Hill promontory, so that between the coal works at Coed Way and these near Shrewsbury the coal strata dip *on three sides towards a common centre.* The coal which is worked at Uffington, three miles north-north-east of Shrewsbury, is a beautiful illustration of the manner in which this zone, following the sinuosities of the more ancient rocks, reappears at intervals upon their flanks, for there the same purple Cambrian sandstone, as in the Longmynd, Lyth Hill, &c., (the most ancient rock in this region and underlying the whole of the Silurian System) rises in an insulated mural form constituting Haughmond Hill. The little patch of coal measures, occupying the low ground between that hill and the river Severn, contains the usual freshwater limestone of the district, associated, however, with one seam only of workable coal, as proved by the following section.

*Shaft section of the Coal-pits at Uffington.*

| | | Yards. | ft. | in. |
|---|---|---|---|---|
| | Drift clay with boulders or red gravel | 14 | 0 | 0 |
| Passage from Lower New Red into Coal measures. | Red clods[1] | 5 | 1 | 0 |
| | Poundstone | 1 | 0 | 0 |
| | Red clods | 2 | 0 | 0 |
| | Grey clods, dark colours above, light below | 2 | 2 | 0 |
| | Poundstone | 1 | 0 | 0 |
| | Red curly rock | 1 | 1 | 6 |
| | Grey clod | 2 | 0 | 0 |
| | Red rock with grey partings | 2 | 2 | 0 |
| | Poundstone with some red (red marly clay) | 1 | 1 | 1 |
| | Bassy coal (mush or impure coal) | 0 | 0 | 6 |
| | Poundstone | 1 | 0 | 0 |
| | Coal | 0 | 0 | 6 |
| | Poundstone both tender and strong | 4 | 0 | 0 |
| | Hard white and brown rocks (sandstone) | 3 | 0 | 0 |
| | Clumper beds, Rattlers (concretions), red and white clod | 5 | 2 | 0 |
| | Mush, or impure coal | 0 | 1 | 0 |
| | *Limestone* of similar structure and containing the same organic remains as that of Pontesbury | 1 | 0 | 0 |
| | Reds | 5 | 0 | 0 |
| | Blue clods and roof of coal with plants | 7 | 0 | 0 |
| | Coal | 1 | 0 | 0 |
| | Poundstone | 2 | 1 | 0 |

Beneath this lies a whitish sandstone rock with brown stripes and other measures overlying the only bed of good coal, which is worked at a depth of thirty-five yards below the limestone.

In the works at Uffington an effort was lately made to find the lowest of the two coals, which in so many parts of this district occur below the limestone; but like the upper coal it proved to have thinned out and disappeared, for at a few yards beneath the coal,

[1] In this and other sections descriptive of shafts the sides of which were not open to inspection when I examined this country, I am compelled to use the terminology of the miners. The red clods here alluded to are the argillaceous (often saponaceous) *marls,* which form the beds of passage from the Lower New Red into the carboniferous strata.

the trial shaft reached the purple schistose greywacke (Cambrian) inclined in nearly a vertical position. A slight acquaintance with the mineral structure of this part of the country would at once have checked the further prosecution of a work which had reached the lowest rock, the fragments thrown up at the mouth of this shaft being identical in structure with the adjacent rock of Haughmond Hill; but notwithstanding such palpable evidence the speculator continued *to sink* for fifty additional yards in these ancient beds, and was surprised that no change of metal was met with, though the youngest geologist would have told him that no change could occur where strata, of infinitely older date than any connected with the carboniferous system, were in a vertical position. To point out more clearly the folly of this and similar attempts I annex a small general section of this little carboniferous patch, showing its relations to the ancient and barren rocks on which it rests. (See section, Pl. 29. fig. 6.) The coal strata here dip north-north-west at a slight angle, and, as appears in the diagram, they are subject to many faults, the chief of which run from north-north-east to south-south-west. From Uffington we must travel some miles to the east or south before we reach any other patch of coal, the intervening tracts being occupied either by old Cambrian rocks rising to the surface, or covered by the lower members of the New Red Sandstone and great accumulations of gravel. It is probable, however, that on many points the coal has never been deposited, since we occasionally see the Lower New Red Sandstone reposing directly upon the older rocks.

One small deposit is found at Dryton, on the south-western slope of the Wrekin; and in the more superficial parts of it, near Longwood, coal was long ago extracted; but it has more recently been followed to a greater depth at the former place, where two seams are now in work. The shaft is thirty yards deep, eighteen of which are sunk through overlying detritus of red sand and pebbles, &c. The uppermost of the beds of coal is two feet, the lowest three quarters of a yard thick, separated by clods and sandstone, and there are no traces of the limestone or of the third bed of coal. The dip is three inches in a yard to the south-east.

On the south bank of the Severn, the bay formed in the older rocks between the ridge of the Caradoc on the east, and Lyth Hill on the west, abounds with carboniferous patches, which vary in the amount of their productiveness, precisely in the ratio of the depth at which the underlying rock is found. For example, at Cound, Pitchford, and other places, where these old rocks (Upper Cambrian) occasionally protrude to the surface, the adjacent carboniferous strata are mere shreds, sometimes covered by the newer Red Sandstone, but towards the centre of the trough the coal strata thicken, and at Le Botwood, near Longnor, we again meet with nearly the same development as in the Pontesbury field. These beds dip east-north-east 10° or away from the contiguous promontories of older rocks. The shaft at Le Botwood is sixty-three yards deep, passing through shales, limestone, and coal. The shale or roof of the coal is particularly rich in plants, and those which I collected were identified by Professor Lindley and form part of the list previously given.

The limestone at Le Botwood is extensively burnt for lime and is identical with that of Pontesbury and Uffington, containing also the *Microconchus carbonarius.* It is about two yards thick and lies from eighteen to twenty yards below the surface. A three-feet bed of coal, found at eleven yards below the limestone, is of a sulphureous quality; and six yards still lower is a seam, twelve inches thick, of good coal. In the limestone, besides the usual shells, the remarkable species of fish *Ctenodus Murchisonii* (Agassiz) was found by the very Rev. Archdeacon Waties Corbet; and Professor Phillips detected, in the shale, remains of the *Megalichthys Hibberti,* &c. On the western edges of this bay, amid the older rocks, coal has been worked near Pulverbatch, Wetrains, &c.; and on the eastern side it has been detected, and was partially worked in former days, running up in small transverse valleys towards the Caradoc and Acton Burnell hills. One of the most curious of these thin patches is displayed on the west bank of the brook at Pitchford. The whole carboniferous series is there represented by a bituminous breccia, from ten to twelve feet thick! which is partially covered by the New Red Sandstone, and rests upon the highly inclined edges of a greenish greywacke sandstone (Cambrian rock), similar to that of the Longmynd.[1]

The highly inclined edges of these Cambrian rocks, which rise to the height of only from twenty to thirty feet above the brook, are, on the western side of it, covered with the carboniferous breccia arranged in horizontal layers; but as the works were abandoned when I visited the spot, I could not observe the junction between these beds and the inclined edges of the older rocks. This breccia is composed of fragments of the underlying Cambrian rock, on the surfaces of which are casts of ferns and other coal plants, the whole being cemented by bitumen and decomposed sandstone. The beds were formerly much quarried, and the breccia being transported to Shrewsbury, and there subjected to heat, a liquid bitumen was extracted, which, when prepared, was sold as a medicine under the name of "Betton's British Oil." Contiguous to this quarry is a well, on the surface of which is a constant accumulation of bitumen exuding from the adjoining strata. It will hereafter be shown that where points of trap rocks penetrate the adjacent strata of the Cambrian system there are frequently bituminous exudations near the points of contact.

From the preceding details respecting the carboniferous deposits near Shrewsbury, it appears, that the coal was formerly worked in those spots only where it actually rose to the surface; and that, even at the present day, the speculation has not extended to any considerable distance beyond the mere outcrop. In the small irregular troughs at Longnor, Uffington, Longden, Le Botwood, Pitchford, &c., where it is evident from the nature of the sides of the trough, and also by the shallow depth at which the Silurian and Cambrian rocks are met with, that no coal can exist, further trials would be absurd.

[1] I consider the green hard greywacke sandstone in the Pitchford Brook, on which the coal breccia lies unconformably, to be a part of the upper Cambrian System prolonged from the Longmynd. (See Map.) In the brook Mr. Aikin remarked the intrusion into the schist of a green stone trap.

An examination, however, of the country on the south bank of the Severn has convinced me, that coal may be profitably extracted to a certain extent in the tract lying between the Pontesbury and Asterley coal-pits, and the escarpments of the dolomitic conglomerate, and Lower Red Sandstone of Cardeston and Alberbury. Trials in this district or in the adjoining tract, south-west of Cardeston, could be made at small expense, it being highly probable that if the coal measures are not cut off by the rise of older rocks, which is discountenanced by the form of the country, they are only covered by the thick accumulation of gravel and argillaceous clay which overspreads this depression. At the same time that we give apparent good reasons for finding the thin or upper coal strata within a limited area, it is fair to state, that practical observation militates against the supposition of any great expansion of coal beneath the Lower New Red Sandstone on the right bank of the Severn. In no one of the present works does it appear that the seams of coal become thicker or increased in number when followed downwards on the dip. And although these trials have hitherto proceeded to so short a distance, that no very decided conclusions can be drawn, yet it must be allowed that they weaken the supposition of the thin or upper coal-measures graduating downwards into richer fields. We might, indeed, surmise that this zone of coal, which, judging from the nature of the limestone, was probably accumulated in a lake or near the mouths of rivers, has merely resulted from a very *partial* accumulation of vegetables upon its shores, and that *beyond* the drift or range of these small gatherings of wood we should look in vain for a mineral formed out of such materials. It might also be said that as these carbonaceous zones of the plain of Shrewsbury differ so essentially from the largely productive tracts of coal in the absence of the underlying deposits of carboniferous limestone, millstone grit, &c., we ought rather to presume, that the mineral thus wanting in its accustomed associations would be feebly developed. On the other hand, it may be contended, that according to analogies elsewhere, carbonaceous matter formed upon the natural edges of such a basin would naturally thicken towards its centre; or, in other words, that as a certain amount of vegetable matter had been accumulated upon the shores of these ancient rocks, still larger quantities were probably washed down their shelving sides into the depths of a capacious bay or estuary, on the opposite limits of which we actually meet with other and highly productive coal-fields rising from beneath a cover of New Red Sandstone. I do not throw out such suggestions as an inducement to proprietors, north of Shrewsbury, to endeavour to penetrate the thick and massive deposits of which the overlying New Red System is composed; although it is by no means impossible that a coal-field may there lie hidden, which when the more *accessible coal strata* in other tracts shall have been exhausted, may prove of value to future generations. Such an inference is rendered more probable by the observations in the next chapter, which show, that a band of coal measures of the same age, passing similarly upwards into the New Red Sandstone, and containing a limestone identical with this of the Shrewsbury plain, distinctly *overlies* the edges of the most productive

of all the Salopian coal-fields; and hence it is no strained inference that carbonaceous masses equally thick may also be found expanding beneath this upper coal of Shrewsbury, though most probably at some distance from the outcrop, and if so, necessarily at *vast depths* under the New Red Sandstone of the plain of Shrewsbury. Observations leading to similar inferences, and extending their application to other extensive tracts in the central counties, will be found in subsequent chapters. Again, however, I would repeat that much caution and many preliminary trials towards the edges of this great basin are required before such speculations are attempted, since it is one thing for the geologist to show the *natural position* of the coal, and another for the miner to determine where it has been locally accumulated in any quantity worthy of the industry of man. This latter point may be most safely ascertained by following the coal seams upon their dip from the points where they are now known, and if they continue to thin out in their extension beneath the red sandstone, then, indeed, deep sinkings in the central parts of the basin north of Shrewsbury would be absurd. The proofs which will be adduced in the eleventh chapter, of the thinning out of the coal seams of the Oswestry field where they dip under the Lower New Red Sandstone, point to the necessity of much circumspection in all such operations.

Passing from these practical hints, I would conclude with a few general theoretical reflections. These poor and thin stripes of coal measures have been dwelt upon in some detail, and similar patches will again be adverted to in the following chapter, on account of their peculiar character and high geological interest, in aiding the proofs of a descending passage from the Lower New Red Sandstone into the Carboniferous System. Constituting the youngest member of that system, they fill up an interval in geological chronology, precisely in that portion of the series in which much obscurity previously existed; for, with the exceptions in the North of England pointed out by Professor Sedgwick[1], it was the prevalent belief of geologists when my researches commenced (1831), that in all *other parts* of England a great break existed between the New Red System and the coal measures, the phenomena of disruption in the environs of Bristol being assumed as the true types or patterns of the general order. These upper coal measures of Shropshire are further remarkable in bringing to light, for the first time in Great Britain, a peculiar limestone interstratified with coal seams, and which from its prevalent organic remains and mineral composition I have referred to freshwater origin. Though never exceeding eight or nine feet in thickness, and sometimes dwindling away to two feet, this band is so remarkably persistent, that when followed along all its sinuosities the length of its course is about forty miles; and even in a straight line from Coedway, near the Breidden Hills, to Tasley and Coughley, near Bridgenorth, where it will presently be described, the distance is not less than twenty-five miles; and yet throughout such a space this little stratum preserves the same structure, and contains

[1] See Geological Transactions, vol. iii. part I.

the same microscopic shell, *Microconchus carbonarius*. The subsequent discovery by which the limestone of Ardwick, near Manchester, was identified with it, has given to this stratum a considerable additional importance, in carrying out over so wide an area the evidences adduced in this volume of the passage of the coal measures beneath the New Red Sandstone of the central counties[1]. Besides the zoological proofs of this limestone having been formed in fresh water, I have already stated, that in mineral characters it strongly resembles the lacustrine limestone of central France, and I may now add that the origin of the rocks in the two countries is probably connected with similar causes. For as Auvergne is a region which has been eminently subjected to volcanic action during past ages, so its extensive formations of finely levigated limestone are supposed to have been the produce of hot springs (the usual attendants on volcanos), holding calcareous matter in solution, and depositing it amid the fine silt of ancient lakes. In like manner the whole of the surrounding region of Shropshire, in which this limestone occurs, is absolutely perforated by intrusive rocks of igneous origin, (see Map); and hence it is a fair deduction, that the peculiar limestone of this tract may likewise have been the result of volcanic hot springs. Other analogies will strike those to whom the phenomena in central France are familiar, such as bituminous exudations and sources of mineral pitch which issue from the surface at those points where eruptive rocks protrude; but these comparisons belong more properly to subsequent chapters. Difficult as it may be to reconstruct in imagination the condition of the surface of this part of our island during the period of the coal formations, the limestone and associated beds (whether formed exclusively in *pure* fresh water or in bays in which fresh predominated over salt water) afford convincing proof of the existence of neighbouring dry land, from which rivers flowed, transporting terrestrial vegetable remains, and entombing them with shells, the greater part of which must, unquestionably, have lived in fresh water. That such streams, however, were *near* the sea, and that in fact they soon passed into estuaries, will be presently rendered evident by details of the undeniable alternation and intermixture of freshwater, terrestrial, and marine remains in Coal Brook Dale, which tract, though only distant a few miles from that under consideration, exhibits a vast expansion of the carboniferous strata; thus leading us to suppose, that whilst the Shrewsbury deposit has been simply formed by streams issuing from the Cambrian and Silurian region, and giving rise to lakes to which the sea had little or no access, the greater carbonaceous masses of Coal Brook Dale have been accumulated by the same waters where they united to empty themselves into an estuary[2]. The north-eastern edges of this

[1] Mr. Greenough informs me that he has observed a bed of limestone interstratified with coal in Warwickshire which he considers to be of the same age, but he has not observed any organic remains in it.

[2] A point of high comparative interest attached to these coal-fields of the central counties, is that they contain fossil fishes, mollusks and entomostraca, identical with or closely allied to species abounding in the rich fossil accumulation at Burdie House near Edinburgh, the description of which by Dr. Hibbert justly excited so much attention. Though not, perhaps, quite so copiously charged with organic remains as

great marine bay were formed near Manchester, its western margin being marked by the zone of carboniferous limestone which bounds the coal-fields of Oswestry, Chirk, and Ruabon. An inspection of a general geological map of England will indicate the extent of the area, which now appears as a vast trough of New Red Sandstone encircled by carbonaceous deposits. (See wood-cut 4. p. 25.) Further observations upon the origin of these coal-fields occur in the ensuing pages, particularly in the concluding part of the eleventh chapter, where a small map will be found, explanatory of the probable physical geography of this region during the accumulation of the carboniferous deposits.

the Scotch deposit, the Salopian and Lancastrian strata afford proofs which do not exist in Scotland of their geological place in the order of formations. In England they have been shown to constitute the youngest carboniferous zone, because they graduate upwards into the New Red System. Now, if we are to be guided by the nature of the fossils, we might be disposed also to infer that the beds at Burdie House, where no such stratigraphical proofs exist, and which were once supposed to be of great antiquity, represent after all one of the *youngest* accumulations of the carboniferous system. At all events, if we look at the question on a broad scale, it is manifest from the position in which the Burdie House fossils have been discovered, not only in Lancashire and Shropshire, but also in Staffordshire, that they appertain to those coal measures which overlie the Millstone grit. (*See chapter on the Dudley coal-field.*)

Mr. Leonard Horner has shown (Edin. New Phil. Journ., April, 1836,) that the mixed nature of the organic remains at Burdie House compel us to suppose, that the carbonaceous strata at that place were accumulated in an estuary and not exclusively in fresh water, although their contents had doubtless been poured forth by streams. This subject will be beter understood after perusing the following pages, particularly the conclusion of the eleventh chapter.

# CHAPTER VII.

## COAL-FIELD OF COAL BROOK DALE.

*Upper Coal and Freshwater Limestone.—Lower Coal or productive Coal and Iron field.— Carboniferous Limestone.— Trap Rocks and Dislocations.*

FROM the thin and slightly valuable carboniferous tracts around Shrewsbury we now proceed to the consideration of the great productive coal-field of Shropshire, in which are found nearly all the members of the carboniferous system. Geologists owe their earliest knowledge of this coal-field to an interesting memoir by Mr. A. Aikin, published twenty-six years ago in the first volume of the Geological Transactions[1]; and recently a fresh mass of most instructive and curious information respecting it has been brought forward by Mr. Joseph Prestwich. As soon as I found that the last-named geologist was assiduously studying the structure of this remarkable district, I willingly referred all details to his enterprise, being aware that the region over which my inquiries ranged, was too large to permit of minute attention being paid to the intricate relations of this highly dislocated tract. To his forthcoming memoir in the Geological Transactions I therefore refer such of my readers as may require precise detailed knowledge, confining my own observations chiefly to the general features of the carboniferous strata and their relations to the surrounding deposits.

Occupying both banks of the Severn at Madeley and Broseley, the principal and most productive portion of this field spreads out to the north of that river in a large triangular-shaped mass, the apex of which terminates at Lilleshall. (See Map.) To the south it is flanked by the Old Red Sandstone and upper Silurian rocks; to the west by a thin zone of the lower Silurian rocks and by the trap rocks of the Wrekin and Ercal Hills. Throughout more than two thirds of its circumference, i. e. to the north-west and east, this tract is bounded and overlaid by the Lower New Red Sandstone; but the passage from the coal measures into that formation is not so clear as in the Shrewsbury

[1] Mr. A. Aikin had prepared a vast quantity of geographical data, illustrating the structure of this tract, which he lent to me. With his permission I subsequently placed the maps in the hands of Mr. Prestwich, who has made an excellent use of them. His inquiries commenced after I had pointed out the stratigraphical and zoological distinctions between the *carboniferous* and *Silurian limestones* of this neighbourhood, (Steer-away, Lilleshall, Wenlock, &c.)

field, being generally obscured by accumulations of drifted matter, or rendered difficult of investigation by the numerous faults which run along the boundaries. To these obstacles we may add, that no attempts like that of the Earl of Dartmouth (p. 58.) have yet been made to follow out the coal beneath the red sandstone. If, however, we make a transverse section from the coal works at Donnington across the hills on the east, and pass near to Lilleshall Abbey, we see that where the works are nearest to the line of red sandstone, the coal strata dip to the east or beneath the adjacent sandstone. This coincidence of inclination in the red sandstone and coal measures may be observed at several points between Lilleshall Abbey on the north (see section, Pl. 29. fig. 15.), and Prior's Lee on the south. Between Prior's Lee and the banks of the Severn near Madeley the boundary is still affected by faults, but at Rowton near Broseley Mr. Prestwich has detected a passage from the upper carboniferous strata into the Lower New Red Sandstone, similar to the one described in the Shrewsbury field. The same relations are seen on the edge of a thin and broken zone of carbonaceous strata, which describing a tortuous outline, ranges by Coughley to the Wren's Nest upon the right bank of the Severn, and is thence deflected by Coal Moor into a low ridge extending from High Trees to Tasley. At Tasley a single thin bed of impure and poor coal is worked by windlasses, at depths varying from twelve to thirty yards. In the overlying strata is a bed of limestone about three feet thick, identical with the freshwater limestone of the Shrewsbury field. A section of these beds exposed in an open work near Tasley gives the following succession. (Pl. 29. fig. 12.)

| | ft. | in. |
|---|---|---|
| Green and yellow shale, decomposing to stiff clay, passing into a thick ferrugino-calcareous layer | 6 | 0 |
| Limestone, compact and cream-coloured, with *Microconchus carbonarius* and *Cypris*. (The rock of Pontesbury and Le Botwood, see pp. 94 & 97 | 3 | 0 |
| Blue and grey shale | 3 | 0 |
| Sandstone of greyish colour with carbonaceous matter and fragments of plants | 4 | 0 |
| Blue bind or carbonaceous shale forming the top of coal | 2 | 0 |
| Smut or impure coal | 0 | 6 |
| Clod or argillaceous shale | 0 | 2 |
| Coal | 1 | 4 |
| Stiff mottled red and green shale, depth unproved. | | |

This coal contains in some parts thin laminæ and veins of white calcareous spar. It is further to be observed that much of the carbonaceous matter is in an unconsolidated state, exhibiting the matted fibres, leaves, and stems of the plants. This structure, indicating an intermediate stage in the formation of coal, is not of unfrequent occurrence in the upper secondary and tertiary carbonaceous deposits in various parts of Europe; and although not often seen in the most ancient coal, I have observed it in other parts of Shropshire and also in the Dudley field.

The upper coal measures, reposing upon the Old Red Sandstone of Aldenham and Shirlot, dip to the east, an inclination which would carry them directly beneath the Lower New Red Sandstone of Cantern Bank and Astley Abbots if they were not met by the prolongation of what Mr. Prestwich

has termed the main fault. Thin patches of coal, similar to that of Tasley, occur at Caughley and at Kingslow, in both of which places the same band of limestone, four to five feet thick, occurs overlying the lower coals and rising almost to the surface. The beds dip to the east at Kingslow and to the north-east at Caughley, and on the whole may be said to have a slight easterly inclination.

We thus find this *very remarkable* band of freshwater limestone in situations more than thirty miles from its western termination near the Breidden Hills, again associated with coal and passing upwards into the Lower New Red Sandstone; and hence it is clear, as inferred in the last chapter, that we must consider the zone to which this limestone is subordinate, as the youngest member of the carboniferous series. Neither the coal, limestone, nor any one of the associated strata in these deposits is of great persistency, but each of them thins out and reappears at intervals. The poor and detached coal-bearing strata to the south of Bridgenorth, which dip away from the Old Red Sandstone, and have been already alluded to as rising conformably from beneath the Lower New Red Sandstone of Chelmarsh, are for the most part of the age of those at Tasley and Caughley, and will be subsequently described in conjunction with the coal measures of the Forest of Wyre[1].

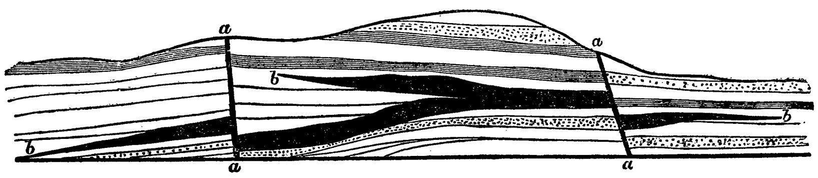
*Lower Coal measures or productive Coal- and Iron-field.*—After this supplementary account of the strata composing the *upper* coal measures described in the previous chapter, and to which the attention of geologists has never yet been sufficiently directed, the following very brief sketch of the *lower* or great productive mining portion of this valuable tract may be sufficient; for, it is not easy to give a very precise notion of the structure of this portion of the field without entering into a variety of details foreign to my purpose. The labours of Mr. Prestwich, however, teach us, that the mineral characters of the same strata often change completely within very short distances, beds of sandstone passing horizontally into clay, and clay into sandstone; that the coal seams wedge out or disappear; and that sections at places nearly contiguous, often present the most marked lithological distinctions. These observations, which coincide with my own in various other coal-fields, demonstrate the hopelessness of determining the respective ages of such rocks in different localities by shaft sections, or a mere comparison of their *mineral* characters. Even the coal itself constantly tapers away and disappears amid the shales and sandstones, constituting what are locally termed "Symon-faults," the character of which, as distinguished from true faults, is explained in the

[1] Mr. Prestwich has informed me that a shaft has recently been sunk near Broseley, which after passing through ninety yards of slightly productive upper coal measures, reached a bed of limestone *four yards* thick, identical in structure with, and containing the same microscopic shells as, the Shrewsbury limestone. (April, 1837.)

It would seem from Mr. Prestwich's observations that the small patch of carboniferous sandstone and shale with a thin seam or two of impure coal which occur at Shirlot on the southern edge of Willey Park, surrounded by and reposing on the Old Red Sandstone, does not belong to the upper but to the lower coal measures. The sandstone on which Shirlot monument is built is a good example of the lithological structure of many of the lower coal rocks.

annexed wood-cut. The vertical or highly inclined lines (*a.*) (*a.*) are true faults, the ends of the coal seams (*b.*) (*b.*) are "Symon" faults.

12.




A section of the Hill Lane Pits near Madeley may be given as an instructive example of the succession in one spot where the strata are pretty fully developed. In a shaft two hundred and thirty yards in depth, we are presented with twenty-one carbonaceous beds, of which the eleven uppermost are sulphureous and impure. Upper coals, similar to those at Caughley and Tasley, alternate with clays, marls, sandstones both argillaceous and calcareous, and with calcareous breccia or conglomerate. Some of these beds may represent the upper coal measures of Manchester. The lower coals, or those extracted for use, which in this shaft are reached at a depth of about one hundred and ninety-eight yards, are named in descending order.

| | ft. | in. |
|---|---|---|
| 1. Viger Coal | 1 | 8 |
| 2. Two-foot Coal | 1 | 8 |
| 3. Little-Ganey | 0 | 7 |
| 4. Lower-Ganey | 1 | 6 |
| 5. Best Coal | 2 | 5 |
| 6. Randle Coal | 2 | 8 |
| 7. Clod Coal | 1 | 4 |
| 8. Little Flint Coal | 2 | 6 |
| 9. Coal under Crawstone | 1 | 0 |
| 10. Lancashire Ladies' Coal | 0 | 9 |
| Total of good Coal in this shaft | 15 | 11 |

In the above list the beds which separate the seams of coal are omitted.

The following table will explain to the reader how little the beds of coal are persistent, and how much they vary in their dimensions in different parts of the field, the united thickness of the mass of coal in any one shaft never being dependent upon the number of the seams.

| Pits. | Thickness of Coal. yds. | ft. | in. | No. of beds of Coal. |
|---|---|---|---|---|
| Hadley | 15 | 0 | 0 | 16 |
| Sneds Hill | 14 | 2 | 2 | 12 |
| Malinslee | 11 | 0 | 10 | 13 |
| Langley | 11 | 2 | 6 | 11 |
| Dawley | 14 | 0 | 0 | 16 |
| Lightmoor | 13 | 2 | 0 | 17 |
| Madeley[1] | 10 | 2 | 10 | 24 (21 to 24.) |
| Broseley | 7 | 0 | 9 | 13 |

The ironstone so largely worked in this field is both concretionary and flat-bedded, but for the

[1] In this table all the coal seams, of whatever quality, are enumerated. In other sinkings, as at Madeley Meadow Pits, as many as twenty-seven seams of coal of pure and impure quality have been passed through.

most part in the former condition, and the various courses of it are known under these names: *New Mine* (peculiar to Madeley) *Crawstone, and Pennystone,* occurring generally: *White and Blue Flats,* in the north and middle districts; *Chance Stone* and *Yellow Stone,* in the middle tract; *Ball stone, Brick stone,* and *Blackstone,* in the northern district. The *Ragged Robins* and *Chance Pennystone* are of irregular occurrence. Of these twelve courses of ironstone more than seven are never found in one locality. In taking a general survey, it may be said, that both the coal and iron are much more abundant in the northern than in the southern part of the field. Mr. Prestwich has indeed remarked the difficulty of identifying any particular stratum of the upper portion over a considerable area, whilst he has found the lower measures stronger and more persistent. Among the various rocks which alternate with the coal and iron, the stone of the Willey or Shirlot obelisk is an example of a coarse variety, while the sandstone occurring immediately above the "flint coal" is of remarkably fine quality for architectural purposes, the monument erected to the late Duke of Sutherland on Lilleshall Hill being built of it. Some of the grits associated with the lower coals pass into coarse conglomerates containing fragments of quartz rock, trap, Silurian and Cambrian rocks; and in the lower measures some of the beds of shale afford excellent fire clay, long celebrated in the manufacture of pipes and pottery.

The ores of iron are peroxides in the sandstone, argillaceous carbonates in the shale, and sulphurets in the coal. The sulphuret of iron is the most abundant mineral, and next to it the sulphuret of zinc or blende, which appears in the ironstone nodules of the Pennystone measures both in granular and crystalline form. Petroleum is of constant occurrence in the upper as well as lower measures; the chief source of this mineral at Coal Port, which formerly afforded one hogshead per diem, being in a thick-bedded sandstone of the upper measures. This supply has, however, much decreased with the opening of the new coal works. Other tar wells have been discovered in the lower coals at Prior's Lee. In some pits, as at Dawley and the Dingle, the petroleum exudes in such quantities that the works are necessarily boarded up or "plated" to prevent its infiltration upon the workmen. Besides these minerals titanium exists in the iron ore, crystals of it having been detected in the refuse slags.

The general relations of the carboniferous deposits to the contiguous formations are explained in Pl. 29. figs. 11 and 16.

## *Organic Remains.*

To the zeal of Mr. Anstice, of Madeley, in collecting the varied and curious organic remains of this coal-field, geologists are signally indebted. Although acquainted with the riches of his stores, the use of which he liberally offered to me as far back as the year 1832, I felt that these numerous and beautiful specimens merited the attention of a separate historian. Shortly after, the district falling under the notice of Mr. Prestwich, the desired object was attained, and all the most characteristic of the unpublished fossils will, I trust, shortly appear in his memoir in the Geological Transactions.

The collection formed by Mr. Prestwich, both by his own exertions and the contributions of Mr. Anstice and others, is very numerous. The terrestrial plants alone amount to between forty and fifty species, composed of *Euphorbiaceæ, Dycotyledons* of doubtful affinity, *Palmæ, Monocoty-*

*ledons* of doubtful affinity, *Equisetaceæ, Filices, Lycopodiaceæ*, &c., the greater part of which are figured in the British Fossil Flora by Messrs. Lindley and Hutton, others by the foreign fossil botanists, Sternberg, Adolphe Brongniart, &c. Of these the *Stigmaria ficoides, Neuropteris cordata, Odontopteris obtusa, Pecopteris lonchitica* (see wood-cut), *Lepidostrobus variabilis*, and *Sigillaria Murchisonii* are common to this and other coal-fields in Shropshire[1].

The animal remains consist of

FISHES, three genera, viz. *Gyracanthus formosus, Megalichthys Hibberti*, and *Hybodus*?, of Agassiz.

CRUSTACEA. *Cypris*; *Limulus trilobitoides* (Buckland). *Trilobites*; three small species, undescribed, and dissimilar to any individuals of this family, which we shall afterwards point out in such great abundance in the rocks of the Silurian System.

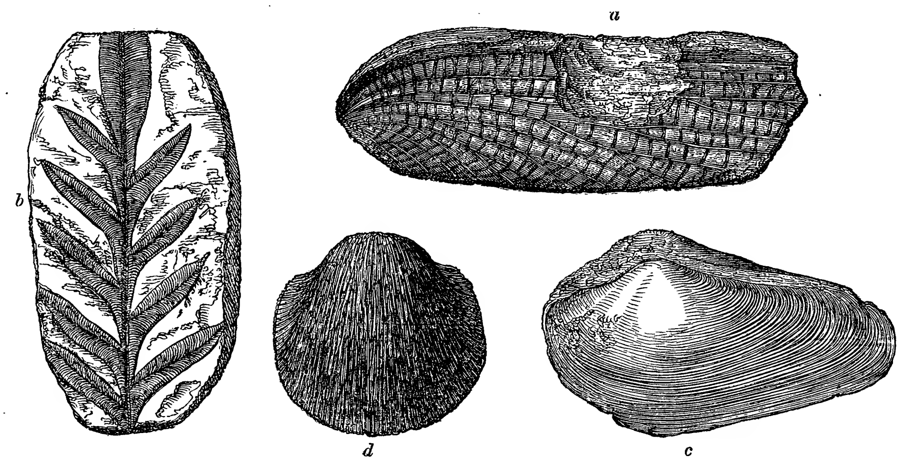
CONCHIFERA AND MOLLUSCA. Upwards of forty species, among which are two beautiful species of *Orbicula, Productus scabriculus* (M. C. t. 69. fig. 1.); *Unio*, two or three species; *Spirifer*, three species; *Nautilus*, four species; *Ammonites* (*Goniatites*?), two species; *Bellerophon*, two species; *Cirrus*, two species; *Orthoceras*, one species, &c. Most of these organic remains have been already figured in Phillips's Geology of Yorkshire, vol. ii., or in Sowerby's Mineral Conchology, as species belonging to the Carboniferous or mountain limestone.

*The published and unpublished species all differ from the fossils hereafter to be described in the Silurian System.* In addition to these fossils, *Insects* have also been found in ironstone concretions, the specimens of which are in the cabinet of Mr. W. Anstice. These are noticed by Mr. Prestwich, and two figures of them have subsequently been published by Dr. Buckland in his Bridgewater Treatise as *Curculionidæ*, most resembling (according to Curtis and Samouelle) African and South American types. Dr. Buckland has with great propriety named one of these *Curculionides Ansticii*, the other *C. Prestvicii*, vol. ii. p. 76. The wing of the insect represented in the wood-cut on the next page has been furnished by my friend Dr. Mantell, in whose rich museum at Brighton it may now be seen. It was previously supposed to be a plant, and was sent to M. Adolphe Brongniart, who immediately perceived that the transverse nervures were unlike anything in the vegetable kingdom, and on being referred to M. Audouin it was pronounced to be the wing of a neuropterous insect closely resembling the living *Corydalis* of Carolina and Pennsylvania.

This copious list of fossils enables us to speculate with some security on the probable conditions under which the various strata of this coal-field were accumulated. Here we find the forms of many terrestrial plants, and even of insects, entombed amid a variety of shells and some crustaceans, the greater part marine, but others, such as the *Uniones* and *Cypris*, unquestionably of a fluviatile origin. The precise relations of the alternating beds containing these various remains are well explained by Mr. Prestwich.

[1] Dr. Du Gard has collected many beautiful fossil plants from this coal-field, particularly large stems, many of which, together with specimens derived from Mr. Anstice's collection, now form part of the museum of the Natural History Society of Shropshire and North Wales, recently established at Shrewsbury.

13.




In this wood-cut are four figures selected from the mass of fossils to indicate the mixed nature of the deposit, viz.

The wing of the *insect* mentioned in the previous pages: its actual size is represented in fig. *a.*

A land plant, fig. *b.*, *Pecopteris lonchitica,* Brongniart, (Lindley and Hutton, Foss. Flor. vol. ii. pl. 153.) A fluviatile shell, fig. *c.* (*Unio acutus*), Sow. M. C. t. 33. f. 5, 6 and 7. A well-known marine shell, fig. *d.*, the *Productus scabriculus,* Sow. M. C. t. 69. f. 1.

Doubtless, therefore, as hinted at in the preceding chapter, this tract of Coal Brook Dale must originally have been a bay of the sea, into which streams of freshwater discharged materials derived from those lands, the contiguity of which has been previously inferred from the existence of freshwater limestone in the adjacent coal-fields. This view is also quite in accordance with that of Mr. Prestwich, who is of opinion, "that the alternations of freshwater shells with marine remains, do not prove as many relative changes of land and sea; but that the coal measures were deposited in an estuary, into which flowed a considerable river, subject to occasional freshes; and he conceives that this position is supported by the fact of frequent alternations of coarse sandstones and conglomerates with beds of clay or shale," containing the remains of the plants which have been brought down by the river. (See the positions (*c, c.*) where such estuary accumulations were formed on the shores of the "mare carboniferum," represented in the small map, Chapter XI.) (*c**.) is the site of Coal Brook Dale; (*a, a.*) the supposed lakes in which the freshwater limestone was deposited.

*Carboniferous Limestone.*—It might be expected that as we descend in the series of strata, we should next meet with the great arenaceous formation, called the "Millstone Grit," which forms the substratum of many other coal-fields, and of which abundant examples will be adduced in the ensuing chapters. But in truth, there are here scarcely any rocks which can be referred to that deposit, unless we consider as its representatives, the grits, conglomerates, and sandstones which form the lower portion of the coal

field; and which contain seams of coal and courses of ironstone almost to the very base of the arenaceous strata. These arenaceous strata rest in several localities upon the true carboniferous or mountian limestone. As this limestone, however, has no great range, and is not of large dimensions, the coal-field throughout the greater part of its extent, reposes at once upon other and older rocks, chiefly of the Silurian System, and in the southern district upon Old Red Sandstone. (Pl. 29. fig. 11.) The carboniferous limestone rises from beneath the coal measures at Little Wenlock, to the north-west of which this limestone appears at Oldfield works, and ranging thence by the Hatch Bank to Steeraway, extends in a narrow ridge from south-west to north-east, nearly two miles in length. This limestone dips to the south-east at an angle of about 45° in the principal works at Steeraway, where it is burnt for lime. (See section Pl. 29. fig. 16.) The beds, eight in number, have an aggregate thickness of eleven yards, but vary individually from five inches to twenty-six each, and are associated with strata of impure limestone, shale, &c., amounting in all to upwards of one hundred feet. The limestone is of a very dark grey, almost black, colour, in which respect, and in being very thick-bedded and not of concretionary structure, it is quite unlike the Wenlock limestone of the underlying Silurian System. The distinction between these limestones is rendered still more complete by the organic remains, which are in great profusion at Steeraway, consisting of shells and corals which are characteristic of the carboniferous limestone in many other parts of Great Britain, and *never* occur in the inferior limestones of the Silurian System. Among these the most prominent are the large *Productus hemisphæricus* and many corals, including *Lithodendron sexdecimale*, Phillips, (*Cladocora*, of Ehrenberg,) which is so abundant, that it constitutes massive beds, particularly the layers of black calcareous shale, which divide the limestones. This black limestone of Steeraway is overlaid by a sandstone, which separates it from the productive coal beds, and is underlaid by strata belonging to the lower limestone shale, consisting of lightish yellow sandstone, with layers of impure limestone and shale, which are interposed between it and the trap rocks of the Ercal and the Wrekin.

All this portion of the edge of the coal-field is much convulsed, trap rocks intruding at many points, so that a patch of the limestone is found adherent to the trap in the village of Little Wenlock, and the mass at the Hatch Works is quite broken off from that of Steeraway. (See Map and Pl. 29. fig. 16.) Limestone, similar to this of Steeraway, was discovered below the productive portion of the adjoining coal-field at Lawley, distant upwards of one mile from the natural outcrop of the rock. It had apparently thickened upon the dip and had become much less inclined. This underground mass was extracted for some time, but the works are now abandoned. The north-western edge of the coal-field is marked by a powerful downcast fault extending from the end of the Steeraway and Ercal Hills to Lilleshall, by which all the lower strata are lost, the productive coal measures abutting against the New Red Sandstone for a distance of nearly five miles. Along this line the coal measures plunge to the north-west, unlike those at the edges of the coal-field at Steeraway, Little Wenlock, and the Iron Bridge, where they dip to the south-east. It has, however, been ascertained by Mr. Prestwich that this north-west dip is only partial, and that the coal strata

rise again with an inclination to the south-east, the flexure being caused by the line of disturbance which proceeds from near Steeraway to Lilleshall, and along which indeed there are traces of the limestone being upcast, accompanied at one spot (the bottom of Hadley inclined plane) by a knoll of trap. (See Map.) On the north-eastern and northern face of the trap rock of Lilleshall Hill, the carboniferous limestone is again brought up, and appears on the sides of the roads and in some old works extending to the high road from Wellington to Newport. It here folds over, or rather is broken up by an anticlinal line proceeding from the trap rock, and by which the limestone itself is thrown into a saddle, dipping both to the east and west. The prevailing dip, however, is to the east-north-east, by which inclination the lime rock is carried rapidly underground, disappearing beneath certain white and red carbonaceous sandstones with impressions of coal plants.

The limestone of Lilleshall is extracted by shafts upon the dip to a distance of more than a mile from its outcrop with a prevailing easterly dip; the deepest shafts (those near the village of Aston) being one hundred and twenty yards. The succession of most of the limestone beds can, however, be best studied in the old open works near the basset. The following is the section, in descending order, of all the strata.

1. Red sandstone, a good freestone, with impressions of coal plants. This rock, which is traversed by the new shafts, is a variety of the millstone grit, similar to that which will hereafter be described at Sweeny near Oswestry, and at Cromhall near Tortworth, Gloucestershire. (Upper limestone shale of Conybeare and Buckland.)

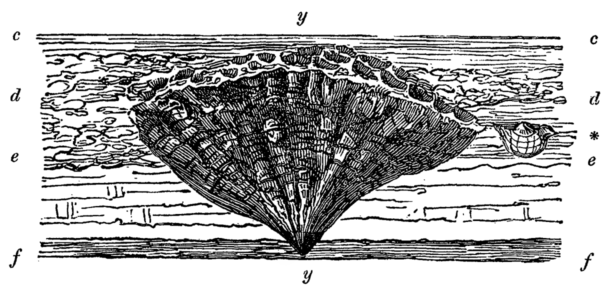
2. Sandstones of purplish pink and white colours, with a few impressions of stems of plants. Thirty to forty feet of this rock are seen at the old open works. These pass down into a very thin flaglike fine-grained sandy limestone, spotted with dark grains of brown oxide of iron; there are also a few small geodes of iron as large as apricots.

*c.* Yellow and red shale.

*d.* *Grum.* Dull dark red and green impure concretionary limestone, in parts ferruginous, each geode being enveloped in red shale. The *Productus hemisphæricus* and another species are most abundant, together with the corals *Lithostrotion floriforme* (Fleming), *Syringopora reticulata* (Goldfuss), and *Lithodendron irregulare* (Phillips) (*Cladocora*, of Ehrenberg). This mass is about twenty feet thick.

*e.* Flat-bedded greyish-green limestone of about a foot in thickness.

*f.* Partial wayboards of red and black shale.



14.

Observing the organic remains in this portion of the quarry, I was struck with the regularity of their arrangement, but especially in the case of the large coral *Lithostrotion* (Lhwydd), *L. floriforme* (Fleming), represented in the above wood-cut[1].

This coral *y*, *y* was two feet five inches wide, by one and a half feet in height. The

[1] From the position of the coral represented in this wood-cut, the generic and specific characters cannot be distinguished. The coral was first determined by Lhywdd as early as the year 1699, and has subsequently received the following names from other naturalists. *Erismatolithus madreporites* (*Floriformis*) Martin. Pet.

lower parts were rooted in the shale (*f*), whilst the upper passed up through the bedded limestone *e* into the mass of red concretions, or "grum," *d*. It appeared, therefore, to be precisely in its original position, and conveyed the impression that it had remained undisturbed beneath the sea, whilst fine red sand at one time, and mud with calcareous matter at another, were deposited around it. Fig. * of the wood-cut represents the large shell *Productus hemisphæricus*, and gives by comparison an idea of the great size of the coral.

The section continued, in descending order, consists of

*g. Splothers*, red small concretionary limestone and shale, much resembling the "*Grum*."

*h. Bulls' Livers*, concretions rather larger than the "*Splothers*." All these overlying beds were formerly worked for lime, but are now abandoned.

*i. Red and black shale.*

*j.* Strong-bedded pinkish red sandstone, with a few pebbles of white quartz. Some of these contain lime in the cement, and are therefore calcareous grits.

*k. Red stone*, *l. Captainer*, *m. Flags*, *n. Strong stone*, *o. Bottom or white stone.* — These constitute the solid subcrystalline mass which is now the chief mine, and which the workmen call the upper measures. They vary in colour from light cream-colour to grey and red, and contain nearly the same fossils as the overlying beds. They are all worked underground in a thickness of about eight yards, separated only by very thin wayboards. The shafts upon the dip have not been sunk beneath the floor of the "white stone."

*p.* Strong-bedded pink and red sandstone, with white quartz pebbles.

*q. Lower or Grey-limestone.* This rock, from ten to twelve yards thick, is only seen on the rise of the strata to the northern end of Lilleshall Hill, where it crops out. Like the other measures it is so associated with red and green shale, in parts micaceous, that in the old open works a casual observer might conceive that the beds belonged to the New or Old Red Sandstone. On fracture, however, it proves to be a dull grey flat-bedded limestone with a purple tinge, gritty, earthy, and impure. Though it did not appear to contain the *Productus hemisphæricus* of the upper beds, I found in it some well-known corals of the other beds of limestone.

This Lilleshall deposit has been described in some detail, because it differs essentially in many of its mineral characters from any of the varieties of the carboniferous limestone, described in the sequel. The organic remains, however, clearly belong to this formation, and are completely distinct from any which occur in the overlying or underlying systems. This is particularly marked in the above-named corals, which I have the authority of Mr. Lonsdale for stating, are unlike the corals of the Silurian System. On the edges of this coal-field, therefore, we are presented with a beautiful illustration of the superior value of organic remains to mineral characters in identifying the age of rocks; for at Lilleshall the carboniferous limestone consists of red and green, and light grey limestone, with abundance of red *concretions*, in parts strongly resembling the "cornstones" of the New and Old Red Sandstone; whilst at Steeraway, only five miles distant, it is a black, dark grey, thick-bedded rock, and void of all concretions. In the one case the associated sand-

Derb., Pl. 43. fig. 3 and 4; *Stylina*, Parkinson; *Columnaria floriformis*, De Blainville; *Astræa mammillaris?* Fischer de Waldheim; *Lithostrotion floriforme*, Fleming; *Cyathophyllum floriforme*, Phillips. Mr. Lonsdale is of opinion that this coral ought to retain the generic name of Lhwydd, which has been adopted by Dr. Fleming.

stones and shales are red, in the other they are white, or yellowish white, and black; yet notwithstanding these discrepancies in structure and in colour within so short a distance, the limestones of Lilleshall and Steeraway are *geologically* identical, and were doubtless formed during the same period and in the same sea, for they contain similar marine shells and corals, and occupy precisely the same place in the series; that is, they are overlaid by and graduate upwards into those sandstones and grits which form the base of the productive coal-field.

The carboniferous limestone is the base of the system under consideration. The characters and relations of the other deposits which lie beneath this coal-field will be explained in a subsequent part of the work; and I shall here merely state that the carboniferous limestone has not in this locality any regular downward passage into the Old Red Sandstone as in other districts. On the contrary, the Old Red terminates at the southern end of the tract, and has never been found beneath the coal measures or mountain limestone on the north bank of the Severn; the underlying stratified rocks throughout the productive coal-field consisting of various members of the Silurian System. Of these the Wenlock limestone or second formation of that system is much the most conspicuous. Rising to the surface on both banks of the Severn, it is presented in juxtaposition to the carboniferous limestone; so that the geologist contrasting the two rocks, can at once perceive their dissimilarity both in lithological structure and organic contents.

Besides these stratified sedimentary masses, there are, however, other rocks of crystalline structure and amorphous forms, (the trap rocks of geologists,) which in a previous chapter have been shown to be of volcanic origin. (p. 68.)

*Trap Rocks.*—The Wrekin may be called the great centre of volcanic action in the proximity of Coal Brook Dale, but the consideration of that elevated mass is necessarily postponed, until the nature of the strata through which it has been erupted has been explained. In the mean time I simply allude to the Wrekin, because the trap rocks of the coal-field on its eastern flank, might seem to be closely connected with it. The volcanic agency, however, by which these contiguous masses were erupted, was in activity at different periods. That which gave rise to the Wrekin, took place during and after the accumulation of the Silurian System, the strata composing which were thereby thrown into inclined positions, before the sedimentary matter composing the carboniferous system was elaborated. At a subsequent epoch, and long after their consolidation and completion, the coal measures were in their turn pierced and traversed by other intruding masses of trap, differing in mineral characters, but erupted on contiguous lines of fissure parallel to that of the Wrekin. These latter outbursts specially relate to the present subject, and I may therefore say a few words concerning them, although the reader will better comprehend their origin and connection, when he shall have perused the chapters in which the more ancient phenomena of the same class are described.

The western side of this coal-field, is most marked by the protrusion of trap. This rock juts out in bosses of irregular shape at and about the village of Little Wenlock, between seven and eight hundred feet above the sea, surrounded by broken layers of carboniferous sandstone and limestone. The most prevalent variety of this trap is a hard crystalline, dark-coloured rock, which may be called basaltic greenstone, though in some cases the grains of felspar are with great difficulty distinguishable from those of hornblende, and then the mass must be considered basalt. Olivine is here and there an ingredient, and in one of the hummocks at the Horse Hays, nearer the centre of the field, the rock contains prehnite, while in the western limit of the tract, there are greenstones of a coarse grain which pass into tufaceous amygdaloids.

Wherever these basaltic rocks appear, the contiguous strata of the coal-field are much dismembered. This is seen not only on and near the surface, but has been proved by numerous underground workings, the full details of which will be found in Mr. Prestwich's memoir. It is sufficient for the present to state, that the trap of this field is very similar to that which in subsequent chapters will be described at greater length, as bursting through and dislocating the coal measures of other tracts, particularly in the Clee Hills, where the phenomena of this class being much more striking will be explained at greater length. This brief notice of the characteristic and prevalent trap rocks of Coal Brook Dale is, however, a natural prelude to a notice of the dislocations of the strata produced by such eruptions.

*Faults.*—The striking dislocations to which the carboniferous strata of this tract have been subjected, are indeed well accounted for by the protrusion of the above-mentioned volcanic rocks. Referring my readers who desire further details to the valuable memoir of Mr. Prestwich, I shall here do little more than direct their attention to the principal lines of fault as laid down upon the map, and to the diagram, Pl. 29. fig. 16., which explains some of the principal fractures. Mr. Prestwich has well observed, that there is probably no coal-field of equal size in the kingdom which has been so greatly shattered as this. It has, in fact, been powerfully elevated from beneath the surrounding Lower New Red Sandstone in separate wedge-shaped masses, the *apices* of which terminate at Lilleshall and Newport. The longitudinal lines of fault by which the field is thus cut up, run nearly from south-west to north-east, and when viewed on the map, resemble the sticks of a slightly expanded fan, the handle of which is the trappean hill of Lilleshall (to be described in the sequel). These lines of greatest fracture are also traversed by cross faults of minor importance, trending from east to west, and north-west to south-east, &c. The most powerful of the longitudinal faults is that which bounds the coal-field, on the east, and separates it from the Lower New Red Sandstone. The coal-measures along this line are not less than one thousand feet thick, and as some of the lower seams of coal are thrown up to the level of the overlying strata of the New Red Sandstone, this upcast (the main fault of Mr. Prestwich) is thus shown to have exceeded one thousand feet, though to what further extent has not yet

been ascertained. Again, in the centre of the field, the masses have been so elevated, that the very lowest beds of the coal measures are brought to the surface, all the superior strata having been destroyed and denuded.

The most powerful dislocation within the field is called the Lightmoor Fault, and is an upcast of more than two hundred yards at the point of its greatest intensity; but it appears that the strata are unequally dislocated at different spots, even along the same line of fault, and in some instances the change of level would seem to have been the result of a series of small dislocations.

General reflections on these phenomena will be offered, as soon as my readers have become acquainted with the more ancient deposits of this neighbourhood, and the various volcanic products with which they are associated. I now restrict myself to the observation, that the north-easterly and south-westerly direction of these faults and basaltic outbursts is *parallel*, to the fissures along which the Wrekin, Caradoc, and other trap rocks of more ancient date have been erupted, and also to the lines along which the Silurian and older sedimentary formations have been elevated.

# CHAPTER VIII.

## CARBONIFEROUS SYSTEM (*continued*).

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*Clee Hill Coal-fields; including the Titterstone Brown Clee; with descriptions of the underlying formations of Millstone Grit and Carboniferous Limestone.*

THE Clee Hills consist of two separate mountainous masses, the most southern of which, called the Titterstone Clee, lies upon the confines of Salop and Hereford, five to six miles east of Ludlow; and the other, or the Brown Clee, is nine to ten miles north of that town. The summit of the latter is 1806 feet, and that of the former 1730 feet above the sea. These hills, chiefly composed of carboniferous strata, are surrounded by Old Red Sandstone, and lie contiguous to the Silurian rocks which form the special object of this work: As they have not hitherto been fully described, it is essential to dwell upon them at some length.

The summits of these ridges are, for the most part, formed of hard and pure basalt, locally called "Jewstone", which being spread over a large portion of the coal-bearing strata in thick tabular masses, is pierced through at many points by shafts for the extraction of the subjacent coal. In the sequel it will be shown, that this basalt has risen up through the carboniferous strata, and has then overflowed their surface. Let us, however, now proceed to view the mineral composition and general relations of the coal measures of these hills, beginning with those of the Titterstone Clee[1].

*Coal measures of the Titterstone Clee.*—Under this term are comprehended all the carboniferous strata which adjoin the Titterstone Clee Hills, and the limits of which will be seen in the map. Within this area lie the fields of Cornbrook, Treen pits, Knowlbury, the Blue stone, the Gutter, and Horse-ditch. All these so-called fields belong, however, to one and the same carboniferous tract, which is of an extremely irregular outline, and is, in fact, divided into several masses, one of which lies in a very

[1] The Clee Hills have been partially described by Messrs. Robert and Rowley Wright, attached to the Ordnance Survey, who also made a geological map of the environs of Ludlow, embracing these hills. Though executed before I had worked out the subdivisions of the Silurian System, this map, which is now deposited in the library of the Geological Society, is very accurate in its general features.

perfectly-formed, small basin. The whole of the space which is marked by a dark colour upon the map is not, however, a *productive* coal-field, but includes those sandstones and millstone grits which support the coal, and which in this and all the other districts cited in this work, are unproductive of coal[1]. The coal-field is flanked on two sides by zones of carboniferous limestone rising from beneath the millstone grit, and the base of the series is the Old Red Sandstone, which wraps entirely around the tract, separating it on the north from the coal-field of the Brown Clee, on the west from the Ludlow rocks, and on the east from the coal-fields of the Forest of Wyre. (See Map and sections, Pl. 30. figs. 1 and 6.) Thus the coal measures of the Titterstone Clee are in portions of their range based upon those rocks which in other parts of England complete the succession of the lower carboniferous strata.

That portion of the field known by the name of Cornbrook, forms an elevated trough, capped by a plateau of basalt. To the south-west of it, and at a considerably lower level, is the small basin of elliptical form, called the Knowlbury field (Pl. 30. fig. 7.), which is distinctly broken off from the great field of Cornbrook; and hangs, as it were, from the skirts of the more elevated tract. This basin is completely exempt from basalt, except that its surface is partially encumbered with fragments of that rock. The Gutter, Horse-ditch, and Blue-stone works are merely the thin or lower coal seams which crop out at various points beneath the escarpment of the larger and overlying basin of Cornbrook. In those parts of this coal-field which are most fully developed, as at Cornbrook and Knowlbury, there are four principal beds of coal, which vary somewhat in thickness in different parts of the district. In descending order they are known by the names of *the Great Coal*, *Three-quarter Coal*, *Smith Coal*, and *Four-feet Coal*. Although only four beds of good coal have been proved in any one shaft or vertical section, there is reason to believe that the coal worked at the Gutter, Horse-ditch, and Blue-stone pits is a fifth or still lower band, which thins out to the eastern and southern parts of this field, and is merely worked at detached points upon the outcrop or basset. The uppermost or *Great Coal* is usually overlaid by a considerable mass of shale and thickly bedded whitish sandstone, known as the "great coal rock". Beneath the great coal, the shale contains a good number of concretions of ironstone of excellent quality, usually exhibiting "Septaria" within, and often containing impressions of plants. They are called the "*Three-quarter* ironstone measures," because they surmount the three-quarter coal. These ironstone nodules are repeated below this seam of coal in the shale beds termed *Clumpers*. Then follows the *Smith coal*, so named from its peculiar value in the manufacture of iron. The *Smith coal* is separated from the "*Four-feet*" coal, by a thick mass of sandstone, with many impressions of plants;

[1] The coal-fields in this region differ essentially in this respect from those of Yorkshire and the North of England, where there are not only coal-fields in the millstone grit, and below it, but also in and throughout the carboniferous limestone.

and beneath the *Four-feet coal* is a hard white sandstone, with red and grey shale. The lowest coal seams repose on the conglomerate and sandstone representing the millstone grit. Such is the general arrangement of the strata, where they are fully developed. The largest and most productive portion of this coal tract, called Cornbrook, is, as before stated, entirely covered by basalt, and the coal is there uniformly worked by shafts sunk through that rock, which varies in thickness from twenty to sixty-four yards. In these works the proprietor, Mr. Botfield, has hitherto confined his operations to the three principal seams above mentioned. The following is a section of the beds passed through in one of his shafts:

| | | | | Yds. | Ft. | In. |
|---|---|---|---|---|---|---|
| Basalt, or "Jewstone" | | | | 50 | 1 | 6 |
| Rotten Jewstones, and brown clunch | | | | 3 | 0 | 0 |
| Blue bind or shale | | | | 3 | 0 | 0 |
| Red rock | | | | 4 | 0 | 0 |
| Pinney stone roof (ironstone) | | | | 2 | 0 | 0 |
| Pinney stone measures (ironstone) | | | | 3 | 0 | 0 |
| Horse-flesh earth (hard clunch of reddish colours) | | | | 3 | 0 | 0 |
| Rock and bind mingled together | | | | 10 | 0 | 0 |
| Blue bind | | | | 2 | 0 | 0 |
| Chance rock | | | | 8 | 0 | 0 |
| Rock and bind mingled together | | | | 12 | 0 | 0 |
| Blue clunch | | | | 4 | 1 | 6 |
| Great Coal rock (sandstone) | | | | 9 | 0 | 0 |
| Great Coal roof (shale, &c.) | | | | 2 | 0 | 0 |
| *Great Coal* | | | | 2 | 0 | 0 |
| Great Coal poundstone | | | | 2 | 0 | 0 |
| Bottom rock | | | | 1 | 1 | 6 |
| Clumper | | | | 2 | 1 | 6 |
| *Smith Coal* | | | | 1 | 1 | 6 |
| From the *Smith Coal* to the *Four-feet Coal*, 3 yards | 3 | 0 | 0 | | | |
| Four-feet Coal | 1 | 1 | 0 | | | |
| | | | | 4 | 1 | 0 |
| | | | | 129 | 2 | 6 |

The Knowlbury basin being free from the cover of basalt is more clearly exhibited than that of Cornbrook. (See Pl. 30. fig. 7.) Its form is elliptical; the major axis being about a mile in length. On the south and west, it is flanked by the Old Red Sandstone; on the north and north-west, by an elevated line of works in the lower coals, called the Gutter; on the north-east, by an escarpment of basalt and the Treen pits (the south-eastern face of the field of Cornbrook); and on the east by the millstone grit and a band of carboniferous limestone. The inclination of the strata upon the opposite sides of the basin is variable. On the west, the lower beds of coal and sandstone crop out at angles of about 30°, resting on the Old Red Sandstone. At the south-western extremity an adit being driven from the lower country of Old Red Sandstone into the heart of the coal works, the exterior or lower carboniferous strata were found in much more highly inclined positions (60° to 70°); but the angle decreased as

the beds converged towards the interior of the basin. In the most depressed or central part, termed locally the "reen", the strata necessarily lie in more horizontal positions. The four principal beds of coal have been regularly worked, and they were all passed through in the adit. The overlying measures will, however, be best understood by consulting the following section made in sinking a shaft 220 yards deep, at the new pit, or nearly in the "reen", or centre of the basin.

| | | Yds. | Ft. | In. |
|---|---|---|---|---|
| I. | Soil | 2 | 1 | 0 |
| II. | Soft yellow sandy rock | 5 | 0 | 0 |
| III. | Blue Pinny ironstone measure, formerly worked | 0 | 2 | 0 |
| IV. | Flam (impure coal) | 0 | 0 | 9 |
| V. | Tough clod | 0 | 0 | 3 |
| VI. | Brown rock sandstone (No. 1.) | 5 | 0 | 0 |
| VII. | Clunch | 9 | 0 | 0 |
| VIII. | Brown rock sandstone (No. 2.) | 3 | 0 | 0 |
| IX. | Strong bind | 7 | 2 | 0 |
| X. | White rock sandstone | 17 | 0 | 0 |
| XI. | Clunch | 12 | 0 | 0 |
| XII. | Ironstone measures (small concretions of ironstone) | 1 | 2 | 0 |
| XIII. | Thick cloddy flam, or carbonaceous shale | 2 | 0 | 6 |
| XIV. | Strong clunch, alternating with grey rock, and containing coal plants | 27 | 1 | 0 |
| XV. | Light grey rock | 5 | 2 | 0 |
| XVI. | Bind | 4 | 1 | 0 |
| XVII. | Measures, with large nodules of poor ironstone | 1 | 1 | 0 |
| XVIII. | Flam (impure coal) | 0 | 1 | 6 |
| XIX. | Hard white quartzose sandstone | 13 | 0 | 0 |
| XX. | Brown clunch | 2 | 2 | 0 |
| XXI. | White rock (sandstone) | 5 | 0 | 0 |
| XXII. | White clunch | 3 | 1 | 0 |
| XXIII. | White rock | 4 | 2 | 0 |
| | | 133 | 2 | 0 |
| | Brought forward | 133 | 2 | 0 |
| XXIV. | Bind | 3 | 0 | 0 |
| XXV. | Hard white rock | 14 | 0 | 0 |
| XXVI. | Hard brown clunch | 10 | 1 | 6 |
| XXVII. | Great coal rock | 13 | 1 | 0 |
| XXVIII. | Hard bind | 5 | 0 | 0 |
| XXIX. | Soft bind | 3 | 0 | 0 |
| XXX. | Stone measure and Great coal roof (plants abundant) | 2 | 0 | 0 |
| XXXI. | *Great Coal* | 2 | 1 | 0 |
| XXXII. | *Three-quarter Ironstone measure* | 1 | 0 | 6 |
| XXXIII. | *Three-quarter Coal* | 0 | 2 | 9 |
| XXXIV. | *Clumper*; a hard black bind, with *ironstone concretions* | 3 | 1 | 0 |
| XXXV. | *Smith Coal* | 1 | 2 | 0 |
| XXXVI. | White earth | 2 | 0 | 6 |
| XXXVII. | Clunch | 1 | 0 | 6 |
| XXXVIII. | Half-way flam | 0 | 0 | 8 |
| XXXIX. | Four-feet coal rock | 3 | 1 | 0 |
| XL. | Bind | 1 | 2 | 0 |
| XLI. | Four-feet coal roof | 0 | 1 | 6 |
| XLII. | *Four-feet Coal* | 1 | 0 | 6 |
| XLIII. | Poundstone | 0 | 1 | 6 |
| XLIV. | Flam | 0 | 0 | 7 |
| XLV. | Hard white rock | 12 | 2 | 0 |
| XLVI. | Clunch, mottled red and white | 2 | 1 | 0 |
| XLVII. | Hard white rock | 0 | 0 | 6 |
| | | 220 | 0 | 0 |

Of the two courses of ironstone now worked, that above the three-quarter coal makes the toughest iron, but the concretions in the "clumper" are richer in quality and have an average thickness of about two feet. Impressions of plants abound in the "Great Coal" Shale, and are also very abundant in the shale of the Gutter-coal[1]; but the most beautiful specimens occur in the nodules or concretions of ironstone, the vegetable

[1] Mr. Lewis, the proprietor of these coal works, is of opinion that the Gutter-coal is a bed distinct from any of those given in the above list. As, however, the section afforded by the adit fairly laid open the whole structure of the field from its base, it is most probable that this Gutter-coal is nothing more than the expansion of one of the lower "flams", or bands of impure coal of the Knowlbury field. Such changes are common in all coal-fields.

having served as the nucleus round which the ferruginous matter has been concreted. Among these plants Professor Lindley has determined the following:

*Calamites arenaceus?* Ad. Brongn. Hist. Vég. Foss. pl. 23. fig. 1.
——— *cannæformis*. F. F. pl. 79.
——— *cistii?* Ad. Brongn. pl. 20.
*Lepidodendron tetragonum*. Schloth.
*Neuropteris flexuosa?* Ad. Brongn. pl. 65.
——— *Loshii*. F. F. pl. 49.
*Odontopteris obtusa*. F. F. pl. 40.
*Otopteris dubia*. F. F. pl. 150.
*Pecopteris lonchitica*. F. F. pl. 153.
*Sigillaria Murchisoni*. F. F. pl. 149.
———. Two unpublished species, one of which I venture to name *S. Lewisii*.
*Sphenopteris caudata*. F. F. pl. 138.
——— *crenata*. F. F. pl. 100. and 101.
——— *furcata?* F. F. pl. 181.
——— *polyphylla*. F. F. pl. 147.
*Stigmaria ficoides*. F. F. pl. 31. to 36.

The greater number of the fossil plants occur abundantly in other coal-fields, (see p. 85,) but the remarkable species of Sphenopteris, *S. polyphylla*, together with the *Otopteris dubia* and *Sigillaria Murchisoni*, have been figured, and so named by Lindley and Hutton, in the Fossil Flora, from specimens collected by Mr. Lewis, in the Knowlbury basin, and forwarded by me to the Geological Society. It does not appear that either the ironstone or shale contains any of the shells which are so abundant at Madeley and other parts of the Coalbrook Dale field.

The Knowlbury coal-field (see Pl. 30. fig. 7.) is traversed by two principal and several minor faults, the prevailing direction of which is from north-east to south-west; and a transverse section, therefore, drawn from Tanner's meadow on the south-east, to the Wint hills on the north-west, passes through these faults, to undersand the relations of which, see Pl. 30. fig. 7.

The first fault (*a.*) offers a marked exception to a prevailing law of faults, first I believe pointed out by Professor Phillips. As the side of this fault sloped away from the place where the coal was lost without underlying, Mr. Lewis, according to the rule alluded to, expected, in sinking downwards, to meet with the coal on the slope, i. e. on what he considered *the downcast side*; but being foiled in his endeavours, he drove upwards, when, to his great surprise, the coal was regained, above its former level, dipping gently towards the centre of the basin. (See Pl. 30. fig. 7.)

There are some remarkable and sudden changes, both in the thickness and composition of the coal seams, which are worthy of notice, as connected with these faults. Between the first and second small faults (*a* and *b*), the coal seams and all the other measures are much thickened, and in parts, doubled, for the space of nine yards. Between the second small fault (*b*), and the "Folly fault" (*c*), the Smith coal is also frequently double its usual thickness. Again, the great coal having an average thickness of about six feet and a half, is abruptly increased to nine and ten feet, in the deep trough included between the Folly fault (*c*), and the Cannel coal fault (*d*). In the rise from the side of the Cannel coal fault to the High fault (*e*), the great coal again expands, and has a thickness of ten feet; but at the upper extremity of the high fault, it is again *suddenly*

reduced to seven feet. There is also a remarkable and apparently sudden change in the mineralogical structure of a portion of the beds of the great coal and of the Smith coal, lying between the Thirty-six feet and High faults; by the interpolation of layers of pure Cannel coal, which alternate with the ordinary coal. The great coal having in this part a thickness of ten feet is divided in the following manner:—

| | Ft. | In. |
|---|---|---|
| 1. Roofs | 3 | 0 |
| 2. The Bat, a pure Cannel Coal, used in turning for ornamental purposes | 0 | 10 |
| 3. The Middles | 4 | 0 |
| 4. Cannel Coal, less perfect than No. 2. | 1 | 0 |
| 5. The Holeing Coal | 0 | 6 |
| 6. The Bottoms | 0 | 8 |
| | 10 | 0 |

The Smith coal contains a layer of three or four inches of Cannel coal, and the Three-quarter coal offers some indication of the same structure. *There is not a trace of Cannel coal in any of these beds on either side of the mass included between these two faults.* In stating this fact, I would also remark that in the two main faults the Cannel coal and the High fault trend in the same direction as the great Jewstone or Basaltic dyke, which will hereafter be shown to occupy a fissure of eruption[1].

Besides those enumerated, there are many minor faults, some of which are mere emanations from one or other of the two great dislocations, and have no very determinate direction. The coal of the Knowlbury field having been in great part extracted, the occupier, Mr. Lewis, has recently made several trials beneath the south-western and north-western faces of the great plateau of basalt, which extends from the Cornbrook works. In the trials on the north-western escarpment of this basaltic cover, called the Hoar Edge, he has sunk two shafts, an account of which will be given in the next chapter, when we endeavour to explain the relations of the basaltic rocks and the mode in which they have been erupted.

## *Millstone Grit.*

This formation, consisting of pebbly, quartzose conglomerate, and thick-bedded hard white sandstone, rises, at many points, from beneath the productive coal-field. It is most expanded in the sterile tract which lies between the northern slopes of the basaltic hills, and the zone of Carboniferous limestone at Oreton. (Pl. 30. fig. 1 and 6.) When that limestone is wanting, the Millstone Grit rests immediately upon the Old Red Sandstone, as may be well seen in the quarries of the southern foot of Titterstone Clee Hill, and beneath the Horse Ditch pits. At this point it passes from a conglomerate into a coarse-grained yellowish and white sandstone of good quality and is extensively worked.

The Cornbrook field is in great measure drained by a large adit called the Cornbrook level,

[1] These faults vary in width from a few inches to forty-five feet, and they are usually filled with broken coal measures, ironstone, &c. In the space between the overlying basalt of the Hoar Edge, and the productive coal-field of Knowlbury, it is said that all the coal formerly extracted lay *in pools or broken masses.*

which in traversing from the south side of the hill to the coal, cuts through a great thickness of the underlying grits and conglomerates. From this work and several natural sections on the slopes of the hills between the Cornbrook coal-field, and the carboniferous limestone, there can be little doubt that this member of the series has a thickness of several hundred feet. The millstone grit is inclined at high angles near its exterior margin, the inclination decreasing as it passes beneath the coal seams. The grits, which are coarse pebbly conglomerates in the ridges above the limestone at Knowl, thin out in their prolongation to the Knowlbury field and pass into sandstone.

## *Mountain or Carboniferous Limestone of the Titterstone Clee Hills.*

This limestone could never have been deposited in a continuous zone, since it appears only in two small masses near the northern and southern extremities of the tract, where it is separated from the productive coal-field by the millstone grit, and thins out between that formation and the Old Red Sandstone. (See Map and Section, Pl. 30. fig. 6.) Let us first consider the southern mass which lies between Cornbrook and Knowl.

This limestone extends in a broken and tortuousb and from the gorge below the Cornbrook level to Bennett's End near Knowlbury, forming a natural escarpment, which rises to some height above the adjacent country of Old Red Sandstone. It terminates at the eastern end in a mural mass nearly vertical, from 15 to 18 paces in width; and at the western extremity near Bennett's End tapers away to a few feet in thickness, dipping beneath the millstone grit and coal measures 60° north-east[1]. In the central part of this zone, the strata are much thicker and less inclined, dipping to the north or to points east and west of that direction, according to the flexures or breaks of the promontories. (See Map, also Section Pl. 30. fig. 6.)

At the Stable and Navers quarries the limestone is exposed in fine precipitous escarpments and is largely worked. The following may be taken as a section of the whole of the calcareous strata, although there is no one natural section, in which all these beds can be seen in the same quarry.

| | Feet. |
|---|---|
| Upper limestone in thin courses with shale | 40 |
| Cropstone | 5 |
| Great limestone or White stone | 54 |
| Limestone shale, &c. | 36 |
| Furnace stone, a strong hard stratum of impure limestone, which from the sand and clay it contains is apt to vitrify in the kiln | 6 |
| Lower limestone shale with thin bands of impure limestone | 60 |
| Maximum thickness in all about | 200 feet. |

Although this may be taken as a sample of the whole of the limestone when fully developed, the appearances in different parts of the escarpment are exceedingly variable. The west end of the quarries at Gorstley Rough, presents merely a thin course of limestone and shale, which expands rapidly to a thick bed of fine-grained oolite resting upon coarser shelly oolite, passing down into a

[1] An adit of Mr. Lewis driven into his coal works from the low country to the west of Bennett's End has proved that there was only a band of conglomerate rock of the thickness of forty-eight feet between the lowest coal measures of Knowlbury and the Old Red Sandstone, the strata being nearly vertical; thus proving that the limestone had completely thinned out.

grey and blue hard encrinital limestone. In the central quarries (Heath's, Navers, &c.) the calcareous shales overlying the *cropstone*, are of red, green, and purple colours, with some calcareous nodules and subordinate bands of limestone, called *Tilestones*, *Rombo*, &c. The *Rombo*, about three feet thick at the Navers quarry, lies about fourteen feet above the *Cropstone*, the intermediate beds consisting of yellow argillaceous marl, and black shivery shale, inclosing thin courses of impure limestone. The great limestone is called the *Whitestone* from its colour, and also the *Bottom Rock* from its usual position. The aggregate thickness of the limestone strata varies from fifteen to fifty-four feet. In some parts the beds are of fine oolitic structure, similar to the rock at Oreton described in the following page (Clee Hill marble). The best beds, whether in a highly crystalline state and chiefly made up of encrinital stems and shells, or having the oolitic structure, are so free from earthy matter, that they are very superior in quality to the argillaceous limestones of the underlying and adjoining Old Red and Silurian Systems. The variegated red, green, yellow, and blue colours of some of the overlying shales, and the pure oolitic structure of some of the beds are the most marked mineral distinctions of this limestone.

The organic remains found here are common to the carboniferous limestone of other districts, and among them may be enumerated—

*Productus Martini*. M. C. t. 318. figs. 2, 3 and 4.
*Spirifer bisulcatus*. M. C. t. 494. figs. 1 and 2.
——— *cuspidatus*. M. C. t. 120.
*Spirifer distans*. M. C. t. 494. fig. 3.
——— *octoplicatus*. M. C. t. 562. figs. 2, 3 and 4.

with several other species of *Spirifer* and *Crinoidea* in abundance. A remarkable Ichthyodorulite, or fin-bone of a fish, was also found in this limestone at Gorstley Rough, by the Rev. T. T. Lewis, which Mr. Agassiz has called *Ctenacanthus tenuistriatus*[1].

The escarpment of this limestone affords an instructive example of the manner in which the strata supporting the overlying coal-field, *have been fashioned into the margin of a basin*, and made to assume their present tortuous outline. The zigzag form, as expressed upon the map, is the result of a number of dislocations, by which the limestone has been thrown at one point into a vertical position, and at others into angles of various inclination accompanied with frequent divergences in the *strike* of the beds. For example, each gulley between the mouth of the Cornbrook level, and the promontory of Knowl hill, marks the line of a separate transverse fault, and at every one of these breaks the limestone is moved out "en echellon," so as to occupy a succession of steps at various distances from the coal-field; the strike or direction of each mass being different. Thus at the eastern end of the zone, the strike is east and west, then follow sundry deviations from that direction in the intermediate ledges; and when we reach what may be termed the great mass of limestone, extending from the "Grove" to the "Ashes," the beds are thrown round at right angles to their former direction. Again they are twisted back to an east and west strike, and by a number of faults and snaps, are subsequently carried into the recesses of Gorstley Rough, beyond which place the calcareous system, as has been shown, thins out and disappears. Besides these dislocations there are numberless minor faults. At the "Ashes" there is one which proves

[1] This specimen is in the Musuem of the Yorkshire Philosophical Society.

a triple complication, consisting of a central conical mass between two other fractured strata, the angle of dip being different in each. (See diagram, Pl. 30. fig. 5.) This face of rock, which has been recently laid bare, shows powerful and forcible dislocation, the edges of the beds on the sides of the central wedge-shaped mass being much shattered. The strike is here south-south-west, north-north-east, and the dip 25° west-north-west. Other dislocations at the Stable and Navers quarries, are accompanied by many contortions. At the point of flexure between the Navers and Gorstley Rough, the fallen masses frequently overspread the limestone with heaps of party-coloured shale, the subsidences of the upper cliff in a single night, interrupting the labour of months[1].

*Carboniferous Limestone of Oreton.*—The limestone of Oreton situated at the northern extremity of the Clee Hills, has the same relations to the overlying and underlying strata as the limestone at the southern end of the carboniferous tract, and constitutes a similar, narrow, broken zone, *thinning out at each end.* In the central portion the strata repose upon the Old Red Sandstone at an angle of about 30°, dipping to the south or to a few points east and west of south. This limestone, however, rises into a low ridge by itself, and is not overlaid by a cap of millstone grit like that above described. (See Pl. 30. fig. 1.) Owing to this favourable position and its superior quality, particularly in the central parts of the little ridge, this stone is very advantageously worked. The beds extracted vary in united thickness from forty to fifty feet, and present the following details in descending order.

Impure shelly limestone and shale.
Top white rock............................ }
Jumbles (a grey-coloured rock) ......... } All these beds of limestone are of good quality, the "bottom whites" the best.
Bottom whites ............................. }
Blue shelly limestone.[2]

At the western termination the limestone is associated with much shale in the following manner:

Broken limestone .............. }
Thinly laminated dark shale.... } ..........................
Blue limestone ............................................... } These beds of limestone are very inferior in quality.
Shale with irregular courses of sandy limestone.........
Brownish yellow shelly limestone of compact structure.
Solid white limestone slightly oolitic.
Dip 15° to the south-east.

The above sectional lists prove that the quality of the limestone, as before stated, deteriorates rapidly toward the western extremity of the zone, and the same may be said of its eastern termination; for near Farlow Factory and on the left bank of the Rea Brook, a hard and impure variety associated with shale, passes down into a conglomerate, forming

[1] In the Map of the Ordnance Survey which I coloured in the field, and a copy of which is deposited in the Geological Society of London, all these dislocations can be clearly seen.

[2] These quarries have afforded all the finest specimens of the grey oolitic limestone known as the "Clee Hill marble." Columns of great length and breadth have been occasionally extracted. Beautiful examples of these may be seen in the mansions of Oakley Park, Downton Hall, and Hoptoun House.

the top of the Old Red Sandstone. The Oreton limestone, like that described p. 119, is cut through by many transverse faults, on the side of which the strata are thrown up at different angles of inclination and in devious directions, giving to the zone that distorted outline seen upon the map. The Farlow Brook runs through the fissure produced by one of these faults, the limestone on its left bank being broken into separate masses, one dipping west-south-west, another south, and at angles varying from 20° to 60°. However discordant these masses may be in regard to each other, they all repose upon and dip away from the Old Red Sandstone, and pass beneath the unproductive coal measures or millstone grit. In one of the quarries south of Oreton, the strata are suddenly snapped off, and a large mass of the rock being pitched at an angle of 70° to the south-south-east, lies unconformably against the millstone grit of Oreton Common. (Pl. 30. fig. 1.) In the quarries east of the principal road, the beds are thrown round and dip south-south-west at an angle of 45°. They are traversed by large fissures perpendicular to the planes of stratification, and the beds on each side of them are shifted twelve to fifteen feet.

Few organic remains can be detected in the fine oolitic beds, but those in the shale and impure limestone are similar to the fossils of the Knowl or Clee Hill limestone. Although the oolitic structure occasionally appears in the carboniferous limestone of other parts of England, particularly near Bristol, I am not aware of any district which offers such large and massive strata of this variety of rock.

Such are the relations and structure of the carboniferous strata of the Titterstone Clee Hills. These fields are of great economical value, supplying with coal a large surrounding country, including the South of Shropshire, the North of Herefordshire, the whole of Radnorshire, and other large portions of Wales. It is therefore of high import to consider the probable quantity of unwrought coal remaining in them, particularly when, as will be shown in the sequel, the geologist knows, that however extensively the mineral may be discovered in other tracts upon the east, no bed of coal can ever be found in any portion of that large adjacent territory of England and Wales which now procures its fuel from these hills. (See Map and general section.) It has been already stated that the Knowlbury and other works situated without the range of the basaltic rock will very soon be exhausted, and that the chief mass of coal lies evidently beneath the great sheet of basalt, extending from the Hoar Edge on the west to the eastern limits of the Cornbrook works. In this large space there yet remains much untried ground, and there is reason for inferring, that not only a sufficient supply for many ages yet remains within the limits of Mr. Botfield's ground (that which lies to the east of the great basaltic dyke), but that a very large mass of coal may exist under the Hoar Edge to the west of that dyke,—points to which we shall specially advert in describing the nature and position of the associated basalt. (See the next chapter.)

The iron ores and the limestone with which they are associated, in these hills, are

very superior in quality to those of the great Staffordshire field[1], and at first sight it appears surprising, that these valuable products should not be turned to better account. They are, however, excluded from fair competition, by the want of means of transport; and it is painful to record, that with all the spirit and enterprise which can be bestowed on such works, the manufacture of iron in the Clee Hills is attended with little profit. Vast heaps of the finest ore have lain unheeded for many years on the high grounds of the Brown Clee, and it is only by the actual juxtaposition of the coal, iron-ore and lime at Knowlbury, in a lower and more favourable position, that Mr. Lewis is enabled to sell, though at a very small profit, a manufactured article of the very first quality. The construction of canals or rail-roads would soon render the Clee Hills the centre of wealth and industry.

*Coal-field of the Brown Clee Hills.* (Pl. 30. fig. 6. north end, and Pl. 31. fig. 4. south-east end.)

The Brown Clee Hills consist of two distinct elevations called the "Clee Barf" and the "Abdon Barf." The latter is 1806 feet above the level of the sea, and is the highest land in Shropshire. The summits are composed of basalt, beneath, or on the slopes of which, are thin carbonaceous deposits containing seams of bad coal. No basalt occurs in situ on the sides of these hills, but rolled fragments of that rock encumber the surface in many places.

These carboniferous tracts, the loftiest in Great Britain, are surrounded on all sides and separated from each other by the Old Red Sandstone; and as it rises to a considerable height upon the flanks of these hills, the thickness of the overlying coal measures can at once be read off by any geologist. Their dimensions are further proved by numerous works which penetrate them, and in consequence of the Old Red Sandstone dipping inward from the sides of each of the hills, the coal is clearly seen to lie in two elevated and broken basins of shallow depth. See Map and Sections above mentioned.

In some parts of the Clee Barf there are three beds of coal, the uppermost being about two feet, and the second, called the *Batty coal*, about three feet thick, and the third or *single coal* about two feet six inches in thickness. The two upper coals, usually pyritous and of a very inferior quality,

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[1] I need hardly tell my readers that the discoveries by which iron ore was found to be convertible into wrought iron, through the application of furnaces fed with coal, and the admixture of limestone as a flux, have completely driven out of the pale of commercial speculations, all those fields of iron in which the ore is not directly associated with the other minerals required in its manufacture. Such for example was the effect upon the great forest tract in the wealds of Surrey, Sussex and Kent, which formerly supplied the metropolis with iron wrought by charcoal, and which still contains a much greater quantity of iron ore than many of our coal-fields, and often of purer quality. In the last century, before the manufacture of iron by coal was commenced, the ores of the Clee Hills were most largely and profitably worked, though transported to forests on the banks of the Teme, to be smelted with charcoal.

are separated from each other by only about nine feet of clod and shale. The *Batty coal*, indeed, is frequently near the surface, the uppermost bed being often wanting. The only seam worth extracting is the *single* or *bottom coal*, which lies in some places twelve feet beneath the *Batty coal*; but this depth varies in different parts of the hill. The intervening strata consist of clod and shale known by the workmen as *petticoat measures*, *horse-flesh measures*, &c., and of one band of sandstone, about nine feet thick, called the *level rock*. Ironstone nodules of the richest description occur in the lowest part of the series. Much of this coal, particularly that of the upper beds, is in a half-consolidated state, the vegetable fibres appearing prominently in the mass and giving to it the aspect of charcoal. Coals of similar character are much less frequent in the Titterstone Clee field, where they are termed *mother*, but they often occur in the poor and thin coal tracts of Shropshire, and have been noticed in the previous chapter at Tasley near Bridgenorth. The lowest coal rests upon a deposit called the Bottom Rock, which is a hard, white, siliceous sandstone, and is the equivalent of the Millstone Grit. In the ravines upon the flanks of the hills it reposes on the Old Red Sandstone, without any traces of carboniferous limestone. The maximum thickness of this rock does not exceed two hundred feet.

Coal has been wrought on these hills from time immemorial, and numerous old shafts attest the extent of these operations, by which indeed nearly all the best coal has been extracted. As the ground, however, has never been regularly allotted, each speculator having begun his work where he pleased, and abandoned it when he encountered a difficulty, it is impossible to say how much of the mineral has been wasted and what quantity may remain beneath in unconnected and broken masses. On the sides of the Abdon Barf most of the present shafts are shallow, but in former times it appears that a pit was sunk to a depth of seventy yards, first, through a considerable thickness of disintegrating basalt, and afterwards through the *batty coal* to the ironstone measures.

The deepest shafts in the Clee Barf are eighty yards, the shallowest fourteen to fifteen, and between these two extremes, there are pits of intermediate depths. They are all worked by the common windlass, a single man sometimes raising coal from a sixty yard shaft, aided by the counterpoise of only an oaken block or "Jack." Owing to their lofty position these coal works are almost entirely free from water, which, except where it lodges in the decomposed basalt, termed "gravel," percolates as rapidly as it falls through the numerous cracks by which the hills are fissured. The workmen, however, have to contend with rather an unusual natural obstacle to mining, in the winds which blow with great force against this lofty and unprotected district, and which not only render the labour at the pit's mouth difficult, but, without certain precautions, would, at times, entirely stop the works. The most violent winds are from the west and south-west, and during their prevalence the galleries are filled with powerful gusts accompanied with much noise. This furious ventilation prevents, of course, the collection of any fire-damp, so that the Brown Clee miner is compensated for working in these cold and noisy chambers by the absence of all noxious gases[1].

[1] The action of the wind in the galleries is checked by a pipe, one end of which reaches the extremity of the working ground, and the other is fixed in a "suff" or stone bed to a vertical cylinder which rising to the sur-

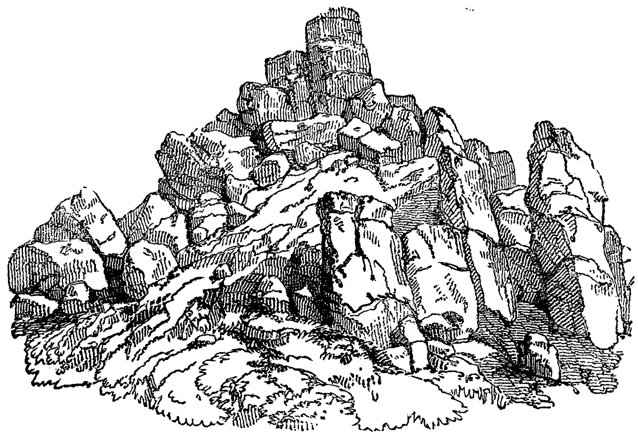
The coal measures of these hills are intersected by a vast number of small faults, one set of which trend from north to south, the other from east to west. In the Abdon Barf there are four principal faults (see Map), two of which have the north and south direction, the other two from east to west cutting the former at right angles. The north and south faults range along the coal measures on the eastern slope of the hills, where no basalt overlies them, one near the junction of the coal with the Old Red Sandstone, the other passing within two or three hundred paces of the cap of basalt. The two transverse faults (termed facing faults) are about eleven yards in width, and affect all the measures and faults up to the edge of the basalt, and are therefore of the most recent date. The north and south faults are upcasts towards the basaltic summit; the principal or lower south and north fault being an upcast of twenty-six yards. The upper north and south fault is only an upcast of about six yards, and neither of the east and west faults exceeds that amount of dislocation. Besides these, there are innumerable minor north and south faults, which are all upcasts reckoning from the Old Red Sandstone of the surrounding low country as a base line. (See coloured section, Pl. 31. fig. 4. south-east end.)

In the Clee Barf the faults are not large, and unlike the Abdon Barf the coal has been proved, if not worked out, under every part of it. In this hill most of the faults are more or less from east to west, producing small and trifling upcasts to the south. The fissures resulting from these dislocations are filled with an indurated breccia of coal measures (clods, shale, sandstone, &c.), the miners persisting that no fragment of jewstone or basalt was ever found in them.

The most extensive of the east and west faults are those by which a large mass of the Old Red Sandstone has been heaved up to the same level as a portion of the coal, so as to occupy the depression between the two basaltic summits, and thus to separate the coal measures into the two small tracts described. (See Map and section, Pl. 30. fig. 6.)

The bare recital of these various dislocations may have caused my readers to infer, that the same beds of coal must be found at many different levels, and they will doubtless also perceive that such disturbances, added to the ascertained fact of the thinness of the coal seams, must ever render the Brown Clee coal-field of slight economical value.

face terminates at the pit mouth in a wooden, trough-shaped funnel. The result of this simple machinery is, that a strong column of air being forced down this cylinder, the wind collected in the chambers is expelled by the shaft mouth, on in other words an equilibrium is established. It is believed by the workmen that the wind enters the galleries through the cracks on the sides of the hills. The men at work at the pit's mouth shelter themselves from the tempest by hurdles secured to large blocks of basalt.



# CHAPTER IX.

## CARBONIFEROUS SYSTEM (*continued*).

*Trap Rocks of the Clee Hills; their composition and relations; effects of their eruption.* (Pl. 30. figs. 6 and 8.)

THE rock which occupies the summits of these hills is, as already stated, a pure basalt. It is indeed of so uniform a structure, that a specimen detached from the Abdon Barf of the Brown Clee Hills, can scarcely be distinguished from one obtained in the Cornbrook or south-eastern extremity of the Titterstone Clee, although these places are about seven miles distant from each other. There are few good natural sections or vertical faces of the basalt, the sides of the hills being encumbered with many large fragments which have fallen from the summits, producing rugged inclined planes. The rock is, perhaps, best exhibited at the culminating point of the Titterstone Clee, called the "Giant's Chair," where it stands out in rude, irregularly-shaped columns (chiefly quadrangular) of four and five feet in diameter and ten to fifteen feet in height, which are crowded together in a confused Cyclopæan pile, as represented in the above wood-cut. Here the columnar shape is the result of joints more or less vertical; but besides these, there are horizontal laminar divisional planes at right angles to the former, which, when the rock occurs in solid continuous sheets as in Hoar Edge and Cornbrook,

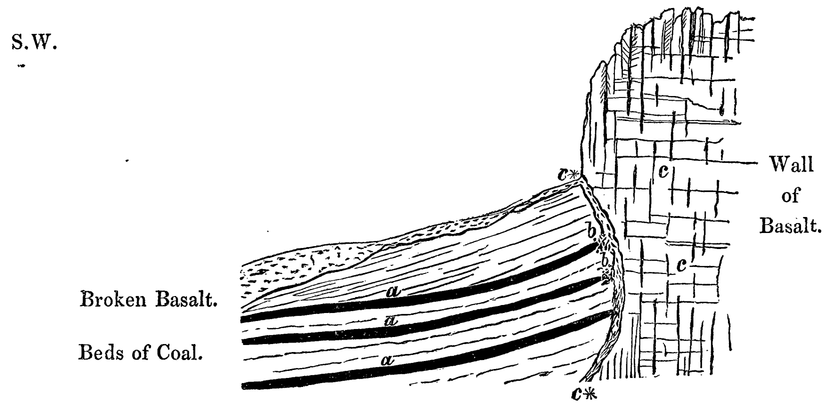
give to the mass an appearance of being stratified. These latter divisions may indeed have primarily owed their existence to the form of the stratified deposits over which the basalt or lava flowed, when first emitted from its vent; whilst the vertical or columnar joints, being at right angles to the surface of the underlying deposits, must have doubtless resulted from the subsequent shrinking of the molten matter, as it cooled down and passed from a soft into a solid state.

It had long been known that the basalt overlies the coal-field in thick sheets, for these are penetrated by shafts, to the depth in some places of sixty-four yards; but it was not ascertained till lately that this basaltic matter had been erupted through the strata of the coal measures before it overflowed them. This idea, as applied to the Clee Hills, was first broached by Mr. Bakewell, who appears to have framed his hypothesis upon evidence collected in a passing visit from some of the miners, respecting what they termed the great "Jewstone" fault; the basalt being known in this country under the name of "Jewstone." I have, therefore, great pleasure in being able to announce that his conjectures were correct, and that recent workings have completely established the fact, that there does exist a subterranean conduit or eruptive channel by which the volcanic matter was protruded to the surface. This phenomenon has recently been brought into a clear light by the spirited exertions of Mr. Lewis of Knowlbury. To comprehend the nature of this discovery it is necessary to refer to the map, in which is marked a somewhat devious line proceeding from south-west to north-east, across the great tabular mass of basalt which covers the greater part of the productive coal-field of Cornbrook. This line indicates a great fault which cuts off the coal-field of Cornbrook on the south-east, from that of the Hoar Edge and Horse Ditch pits on the north-west. This interposition of a wall of basalt was proved by the former workings of Mr. Botfield along the north-western edge of the Cornbrook field. Another proof of basalt having been erupted upon this line of fissure, was detected at a little mine of Mr. Botfield's called the Hill work, where a patch of coal, situated upon and near the south-western termination of this fault (containing the three principal seams,) was fairly worked out and found to be based upon as well as flanked by basalt. (See Pl. 30. fig. 8.) The greatest breadth of this little work, viz., one hundred and fifty yards, seemed to indicate the width of a subterranean channel or tube of eruption. A portion of "the Hill work" within the Treen Pits liberty was also carried down to the basalt, and the beds of coal and ironstone were found to be the same as at the Treen Pits and Cornbrook, with this exception, that the great or upper coal was wanting.

In this state of our knowledge respecting the probable source of the basaltic matter, Mr. Lewis commenced two operations; one to prove the width of the basaltic dyke or channel of eruption; the other to ascertain whether productive coal measures existed under the portion of the basaltic sheet called the Hoar Edge. To prove the width and nature of the basaltic dyke, or "Jewstone fault," between the hill work and the Treen Pits, a shaft was sunk close to the side of the wall of basalt, which there rises to the

height of fifty to sixty feet above the lower ground where the mouth of the shaft was placed.

16.




Various old pits had been sunk at short distances from the wall of basalt, but the speculators had always avoided trials at this very spot, for it was supposed to be precisely upon the continuation of the "Jewstone fault." After penetrating about twenty feet of rotten Jewstones, various measures were passed through, and three of the four beds of coal so well known in these hills were proved. On following the coals (*a*, *a*, *a*,) to the north-east or towards the edge of the plateau of basalt, the three-quarter and the great coal were both found to change their characters, and to become lighter and of little value, and still nearer the basalt they were completely changed into a sort of dull sooty substance, in which all the structure of coal was lost, but in which were disseminated many small flakes of anthracite. This altered mass (*b*, *b*,) was further discovered to be in contact with a *wall of* basalt (*c*, *c*,) which, flanking the charred accumulations, bulged over it irregularly as represented in the wood-cut. The ends of the coal seams in contact with the basalt were slightly turned up, and the junction stuff was coloured red, most probably by the decomposition of the adjoining basalt which was in the state of "rotten Jewstone[1]" for a width of four or five feet. The three upper coals and ironstone measures were all in their regular places. The lower coal was not proved, owing to the inferior condition of the overlying seams. The following remarkable circumstances attend this junction of coal and basalt.

1st. The altered condition of the great coal; the light black matter proving on examination to be still bituminous and to give off flame under the blowpipe, so that however the change in its composition may have been effected it is still capable of yielding carburetted hydrogen gas. The separation from this sooty mass of the small crystalline flakes of anthracite is also a curious fact and worthy of attention.

2ndly. The Smith coal was *un*altered notwithstanding the marked changes observed in the overlying coals, an anomaly which is left for the chemist to explain.

The width of the basaltic dyke being ascertained to be about one hundred and fifty

[1] The miner's term for decomposing basalt.

yards, trials were commenced to determine the second object, viz., the existence of coal measures *under* the basalt of the Hoar Edge, or in other words whether the basalt on the north-western side of the dyke had there flowed over the coal as in Cornbrook. A first shaft was sunk close to the north-western flank of the Hoar Edge, and after passing through a few feet of fallen Jewstone, it traversed a suite of promising coal measures, consisting of shaly sandstone, clunch, bind, clod, ironstone, and grits both coarse and fine, with many impressions of plants and a small seam of impure coal or "flam," all of which, though so near to the basaltic edge, *were little disturbed*. It was, therefore, probable that the contiguous sheet of basalt had not been erupted *very near* to this escarpment of the Hoar Edge, which agreeing with the phenomena observed along the Jewstone dyke, still more confirmed the hypothesis, that the dyke alone had been the chief channel of eruption, and if so that the space of nearly half a mile which is interposed between the north-western side of the dyke, and the Hoar Edge (see Map and Pl. 30. fig. 8.), might be a productive coal-field, like that of Cornbrook, simply covered by a sheet of basalt. This first trial, though thus promising, was abandoned[1] on account of a great influx of water, and a second was commenced with an adequate engine a little further removed from the basalt. The shaft, after passing through ninety-one yards of overlying measures, including a sandstone rock twenty-one yards thick, with the other strata, consisting of "horse-flesh" measures, bind, balls of ironstone, coal smut, &c., reached a four-foot coal of good quality. As the object of Mr. Lewis was to prove the full extent and value of his mining ground, he continued to sink beneath this bed of coal in hopes of finding other seams. After penetrating, however, to the depth of thirty-four yards below the coal, through rocky and grey-coloured clunch with coal plants, and after passing the bottom sandstone rock, instead of discovering another coal seam, he unexpectedly met with a singular mass of a dingy red colour and without appearance of bedding. Having driven downwards in this mass to the further depth of twenty-two yards, without being able to discover the least change in its mineral character, he made a horizontal drift aross it to the west, not far beneath its *summit*. In a few yards the work passed from the red rock into the coarse grit and conglomerate of the millstone grit, the edges of the beds of which were turned up at the point of contact with the red mass. (See Pl. 30. fig. 8.) Mr. Lewis thus saw that he had reached the very bottom of the coal-field, but the nature of the red rock was still a matter of surprise to him. He next drove a gallery towards the opposite side, and rather in an ascending direction, i. e., towards the productive coal-field; and in an equally short distance the opposite extremity of the red substance was reached and the workmen were again in coal measures. At this period I happened to visit the works, and the following data appeared to me to be well established. 1st. As this red rock when first exposed was but little broader than the mouth of the shaft, and at the depth of

[1] It was the intention of Mr. Lewis, when I last visited this county, to proceed again with this shaft, and to connect it with his work, when by his new operation at a lower level he shall have drained the ground.

twenty-two yards had widened considerably, it was proved to be a mass of conical shape rising up through the strata of the coal-field. 2ndly. When quarried underground this singular mass was tolerably hard, but on exposure it became quite soft, crumbling into a number of small round sub-conchoidal lumps. 3rdly. The composition of this rock as well as its intrusive characters proved it to be of igneous origin. The base contains much silex and some peroxide of iron, with disseminated *crystals of felspar*, and it acts slightly on the needle. It must be considered as belonging to what has been called "trap *wacke*" by mineralogists. The strata on the eastern or coal-field side of this intruder consisted of broken clunch, and also of a detached and highly dislocated band of grit thrown quite across the other beds described. (Pl. 30. fig. 8. *a* *.)

Further to ascertain the condition of the ground, Mr. Lewis continued his lower drift horizontally towards the basaltic cap of the Hoar Edge for the length of fifty-two yards from the vertical shaft, carrying it along under the bottom coal rock; and throughout this trial the measures proved to be very regular, little faulted, and dipped at slight angles to the south-east or towards the centre of the basin. This examination, therefore, leads very naturally to the inference, that as the measures approach the centre of the coal-field, the coal may expand, and that Mr. Lewis may one day be rewarded by finding all the other coal seams as regularly in their places beneath the sheet of basalt at the Hoar Edge, viz., on the western side of the Jewstone dyke, as in the great works of Cornbrook before described. (See Map and diagrams, Pl. 30.) There can, indeed, exist no good reason why the coal should not be as largely developed on the one side of the great Jewstone dyke as on the other.

Theoretically, the discovery of the conical mass of trap is of deep interest in explaining the method by which the sedimentary deposits of these hills have been so powerfully disturbed. It was certainly a most happy accident for the geologist, that this coal shaft should have been sunk precisely above the narrow apex of a cone of this rock, and we are greatly indebted to Mr. Lewis, both for continuing his sinking to a depth of nearly seventy feet in this mass, and for his successful endeavours to regain the coal seams, in doing which he determined the form of the intruder. This cone of trap may be supposed to have been the result of an effort towards eruption, which though not reaching to the surface, has produced many of the effects common to such intrusions, whilst the chief source of eruption has been the great jewstone fault, through which all the pure basaltic matter has been ejected, and which reaching the surface has overflowed the principal coal-field in the manner before explained.

*Basalt of the Brown Clee Hill.*—The lithological structure of the basalt of the Brown Clee is, as already stated, in every respect identical with that of the Titterstone Clee, and crowning the summits of the Abdon and Clee Hill Barfs, it also overlies the carboniferous strata in the latter hill. We have not here the same clear proofs of a channel of eruption as in the Titterstone Clee, but from the evidence of some of the oldest workmen, there is every reason to think that the basalt of the Abdon Barf, or the highest point, forms a solid and unfathomable mass, particularly at the northern end. In all other parts of

these hills the basalt is either in a broken state, or has been penetrated in search of coal; but at the northern part of this Barf, trials made eighty or ninety years ago to a very considerable depth, still left off in a mass of solid basalt. We may therefore presume that this was a funnel of eruption, and that from this point the igneous matter flowed over, and covered the coal measures of the adjacent Clee Barf; for there, as before stated, the basalt is a mere sheet which has repeatedly been penetrated in search of coal. If such were the case, vast changes, however, must have taken place since the emission of the basalt; for there is no longer any continuity between the mass on the summit of the Clee Barf, and the point of eruption at Abdon Barf, the higher and the lower summit being separated by a depression occupied by the Old Red Sandstone. The relative altitude, however, of the two hills tends to favour the belief, that the basalt capping the lower hill, originally descended from the higher point of eruption, the intervening or connecting mass having been since denuded.

It has already been shown, that the Brown Clee Hills have been affected by two sets of faults, the one from north to south, coincident with the main direction of the elevated mass or major ellipse of the coal tract, the other from east to west, or transverse to the chief direction of the ridge.

Some of these fractures were doubtless produced after the period of great volcanic activity, though it has been clearly proved, pp. 127, 128, that the most powerful dislocations were directly the result of basaltic eruption. Again, the discovery of the subterranean cone of trap rock described, p. 129, leads us naturally to suppose, that such agents may have caused some of the contiguous faults; for similar hidden and conical masses of igneous rock may exist at other points.

There is, indeed, no difficulty in reading off the method by which this tract has attained its present relations; for here we see a coal-field placed at a higher level above the sea than any other in Great Britain, affording on its sides and in its centre the clearest proofs of having been heaved up into its present position by powerful forces acting from beneath, which have thrown the carbonaceous masses into separate troughs or basins; whilst the ground is rife with volcanic rocks to testify, that the heat which evolved them, and the earthquakes which accompanied them, must have been the agents in dismembering those carbonaceous strata which were once spread out continuously beneath the sea.

Without anticipating subsequent observations I would remark, in passing, that here as at Coal Brook Dale, the best-defined line of outburst, or that of the Hoar Edge and Cornbrook fields, is parallel to other and more ancient lines of eruption in the Caradoc Hills, of which we shall treat in the sequel, as having elevated the Silurian rocks.

# CHAPTER X.

## CARBONIFEROUS SYSTEM (*continued*).

### *Coal-field and Trap Rocks of the Forest of Wyre.*

*Coal-field of Wyre or Bewdley Forest.*—A LARGE tract of country occupied by carboniferous strata, extends from a narrow zone south-west of Bridgenorth to the western flanks of the Abberley Hills in Worcestershire, a distance from north to south of about twenty miles. The greatest width of this tract is in the Forest of Wyre or Bewdley, where it is expanded to five or six miles; but its outline is more irregular than that of any field hitherto described, for in many points it runs out in promontories almost entirely cut off from the chief mass. The tract is bounded on the west by the Old Red Sandstone on which the measures repose, without the intervention of any portion of carboniferous limestone; and to the east, or along the banks of the Severn, by the lower members of the New Red Sandstone, which overlie the coal strata. Some of the detached patches south of Abberley rest upon Silurian rocks. A reference to the map and the general section Pl. 30. fig. 1. which traverses this tract will enable the reader to understand these general relations.

Notwithstanding the large surface which it occupies, this coal tract is of very slight value, owing to the thinness of the beds, and the inferior quality of the coal. Let us now examine the district from north to south. The most northern portion is not more than two and a half miles distant from the little stripe of coal at Tasley, near Bridgnorth, described in the seventh chapter, the intervening space being occupied by both the Old Red and Lower New Red Sandstone.

Poor and pyritous coal occurs occasionally in sandstone and shale from Lower Holycott to near Deuxhill; and coal was also formerly worked at Little Scotland, Ewdon George, and Tedstill. The deposit is thin, the shafts not exceeding thirty yards in depth, and only one bed of poor sulphureous coal was extracted; nor is it possible that more profitable works may be conducted, as the Old Red Sandstone underlies and flanks the coal on all sides. (See Map.) From Glazely to the east of Billingsley, a narrow zone of coal measures occupies both banks of the Borle Brook, on the eastern side of which they are worked in one or two spots, (Chelmarsh Common, &c.). This band contains at least three seams of sulphurous coal, but only one is now extracted. The measures dip slightly to the south-east, passing like those of Tasley, conformably beneath the Lower New Red Sandstone. Here indeed there can be no ambiguity, for the red sandstone with calcareous conglomerate or

cornstone actually occupies the top of Chelmarsh ridge, at the western sides and at the bottom of which these coal seams and associated strata are exposed beneath an *actual cover* of red rock. As there is a perfectly *conformable* passage, in descending order, from the lower beds of the red sandstone through stiff argillaceous shale, greyish white sandstone &c., into the coalbearing strata, we have here an additional example to the many cases of similar passage observed in Salop and in Staffordshire. The uppermost coal, called the little coal, is worthless,—the second, or the top coal, is occasionally worked, and is here twenty-two inches to two feet thick. In the bed of the brook and dipping beneath this coal is a band about a foot and a half thick, made up concretions of impure limestone, a complete coal measure cornstone. It is of a mottled grey colour and much resembles the calcareous zones, in similar geological positions, between Hales Owen and Hagley in Worcestershire. (See pp. 56. *et seq.*)[1] The lowest coal has been worked at a depth of about forty yards beneath the limestone, and is two feet six inches thick.

At Billingsley there were formerly extensive speculations, and shafts were sunk to considerable depths, through three beds of coal, the lowest of which was said to be a sweet coal. The most valuable mineral, however, of these works was the ironstone. The operations, however, terminated in the ruin of all concerned, owing to the impure nature of the coal, and the very dislocated condition of the strata. The carboniferous strata of Billingsley extending to the south, surround the hills of trap rock in which the park and house of Kinlet are situated. There are some fine escarpments of sandstone exposed on the sides of the small brook near the New Buildings. Lower Harcott, however, is the only locality with which I am acquainted where the coal is free from pyritous admixture. It is there extracted in shallow pits on both banks of the rivulet which flows between Kinlet Park and High Green, and from four different seams, which occur in the following descending order:

| | ft. | in. |
|---|---|---|
| Sandstone and shale, thickness variable. | | |
| 1st Coal | 3 | 0 |
| Clods and ironstone | 3 | 0 |
| 2nd Coal, sometimes sulphureous | 1 | 6 |
| Clods and ironstone | 3 | 6 |
| 3rd Coal thins out in some places to 1 foot 6 inches | 4 | 0 |
| Shale and measure | 2 | 0 |
| 4th Coal | 2 | 0 |

These little seams of coal lying so near each other, may almost be considered as one stratum, and ironstone, said to be of good quality, underlies this coal, as at Billingsley. The highly dislocated state of these strata is adverse to profitable enterprize; and the juxtaposition of the trap rocks on one side, and of the Old Red Sandstone upon the other, forbids our speculating upon any considerable extension of the mineral. Indeed the coal crops out in patches on the sloping side of the hills of trap, west of Kinlet Park.

[1] The calcareous concretions in the carboniferous strata of this tract were, as previously stated, first noticed by the Rev. T. England, p. 60. I have great pleasure in thus recording my sense of the accuracy of this portion of that gentleman's observations, though I differ from some of his opinions: in the sequel, however, it will be shown, that the local anomalies are such, that by the study of this tract alone, it was not easily practicable to separate the concretions of the Coal Measures and Lower New Red from those of the Old Red Sandstone.

[2] There is no exact record of these workings. The only coal now extracted is highly pyritous, and lies at about thirty yards beneath the surface. An old workman informed me that there was great confusion and dislocation of the strata, and that in one shaft all the three coals were *squeezed together*.

Though the coal seams are of slight value, quarries of fine building-stone might be wrought in the sandstones which extend over the Forest of Wyre, and are prolonged to the north-east of Stanley-upon-Severn. A beautiful variety of this rock has recently been exposed by Mr. Child on the south-eastern face of Kinlet Park, where blocks of any dimensions could be raised, rivalling in quality the best building-stone of the coal measures of other parts of the kingdom[1]. It would be tedious if not useless to empty memorandum books, in which are noted details of these coal measures, consisting of alternations of thick-bedded sandstone and shale. The banks of the Severn from Upper Arley to Bewdley afford excellent sections of such beds, particularly upon the right bank of that river under Cliff Wood, where grits and sandstones both thickly and thinly bedded, are interlaced with shales of various colours.

At Stanley near Higley, the carboniferous strata wedging out into a narrow zone, flanked on the west by the Old, and on the east by the New Red Sandstone, are thrown unconformably against the latter. (See Pl. 30. fig. 9.) This fault is therefore not analogous to that of Lydney, on the eastern flank of the Forest of Dean in Gloucestershire, with which it has been compared[2]. In the latter case the carboniferous limestone forming a girdle round a very regular coal basin, is suddenly lost, owing to a fault, which brings up the *Old* Red Sandstone into contact with the coal measures; but throughout the Stanley tract, the coal measures uniformly *repose*, at once, upon the Old Red Sandstone, the carboniferous limestone not being in existence; whilst the rock at this point, which from its mineral aspect was *supposed* to be *Old* Red Sandstone, is nothing more than the lower portion of the *New* Red System, which can be followed to Chelmarsh ridge, and is there seen to overlie these coal measures. This rock is here brought abruptly against the coal by an upcast of the latter, as in many parts around the Coal Brook Dale and Dudley fields[3]. (See chapter 4. pp. 57, 60.)

At Stanley there were formerly extensive coal works, which penetrated the overlying coal sandstone to a depth of thirty-three yards, when two seams of poor and pyritous coal were reached at a further depth of eighty-four yards; and beneath other beds of sandstone and white rock was a lower coal, consisting of four small seams, which though in parts slightly sulphureous, was said on the whole to be equal in quality to that of Lower Harcott. These works have long been abandoned, owing chiefly to the bad quality of the coal, and to the strata being dislocated as well as cut off on their western and eastern flanks by the great fault of Higley and Alvely. (Pl. 30. fig. 9.) Horizontal galleries were formerly driven on to the east from these coal works, until the Lower New Red Sandstone was reached, and the fault was completely stripped. (See Pl. 30. fig. 9.)

A mass of these coal measures extends on the left bank of the Severn, about four miles to the High Grounds above Arley Wood. In some parts it is only a few hundred paces in width, as at

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1 The proximity of fine masses of sandstone to the navigable river Severn may, at some future day, excite speculation in these quarries.

2 Messrs. Buckland and Conybeare, South-west of England, Geological Transactions, vol. ii. p. 285.

3 In all the portion of the Map relating to this district, the geologist will perceive great changes in the boundary lines of previous geological Maps.

Shatterford Turnpike-gate, in others it expands to a mile and even more. It is flanked, like the narrow zones of coal at the Borle Brook and Stanley, by Old and New Red Sandstone, and the deposit is thin and of little value: it is also divided through a considerable portion of its course, by a basaltic dyke, on the sides of which the strata are exceedingly disturbed and broken (Pl. 30. fig.3.). Some money has been expended in this neighbourhood, but all the works are now abandoned, with the exception of those near the trap dyke, where the coal is actually thrown up "today," and from which the poorer people extract a scanty supply of fuel.

An equally profitless and still smaller tongue of the coal measures, passes from the Forest of Wyre to the left bank of the Severn, opposite Dowles, near Bewdley. It is bounded on the north by the Old Red, on the south by the New Red Sandstone, and has been partially worked, but the pits were abandoned almost as soon as commenced.

The coal measures near Bewdley, and extending thence by Ribbesford Upper Woods to Stagbury Hill, are still less productive, for they merely consist of the lower grits and conglomerates of the series. The strata are often exposed in highly inclined positions. Thus at Bark Hill near Bewdley, the grits dip south-east 45°, abutting unconformably against the New Red Sandstone, on which the town is built (Pl. 30. fig. 2.) Most of the strata are undistinguishable from the ordinary millstone grit, but in the hills west of Ribbesford, the grains and pebbles of quartz, more or less rounded, are inclosed in a greenish argillaceous paste, which has the appearance of decomposed trap, similar to the tufaceous conglomerate of Hales Owen, in the southern extremity of the coal-field of Dudley. At the eastern edge of Ribbesford woods and close to the banks of the Severn, one of these coal measure conglomerates dips at a high angle to the north-east, and consists of a coarse admixture of rounded pebbles of quartz rock, some as large as a child's head, smaller pieces and fragments of trap rock, porphyry, and much green earth, perhaps derived from decomposed amygdaloids, the cement being slightly calcareous. It is associated with red shale, whitish sandstone, &c. Another variety of these conglomerates occurs at Dumbleton, where it has been quarried to a depth of fifty feet in the following descending order:—

Yellowish clay; yellowish flag-like sandstone; yellow and purple shale; shale, with stony bands; irregular courses of grit, becoming coarser downwards, but separated from each other by thin seams of red and yellow clay; hard argillaceous conglomerate of a greenish colour, containing small pebbles of rounded quartz; and trap rocks including pink compact felspar, some of the size of eggs. The conglomerate is usually in a decomposing state, and is occasionally traversed by strings of crystallized carbonate of lime. These strata, which are nearly horizontal, lie in unconformable juxtaposition to the Old Red Sandstone, and are a continuation of the conglomerates near Bewdley.

On the western boundary of the Bewdley Forest the measures contain a few seams of poor coal, which are worked at King's Wood, Baveney, &c.; but at the latter place the whole series is very thin; and in consequence of the broken and uneven surface of the underlying Old Red Sandstone, the carboniferous strata are thrown into partial saddles and curvatures. At this point the coal measures are distant only about two miles from the eastern limit of the coal grits of the Clee Hills, the intervening country consisting of Old Red Sandstone.

At Bayton and Mamble, south of Cleobury Mortimer, there are numerous coal-pits near the line of junction with the Old Red Sandstone; and coal measures extend over the parishes of Rock and Pensax to the western foot of the Abberley Hills. In some of the pits near Pensax, the shafts are from thirty to forty yards deep, passing through white sandstone; and two coals are worked, of which the upper or yard coal is the best. A third and lower coal, of inferior quality, is not extracted.

At Mamble, where there are also three seams of coal, the two uppermost are separated by only a foot or two of clod, but the third or lower, lying nine yards beneath them, is harder and better in quality. It is from two feet to two feet four inches thick, and is reached by shafts at depths from forty to sixty yards. The beds here dip slightly to the north, and are not dislocated by any faults exceeding a yard or two in effect. This, therefore, is one of the least irregular portions of the sterile coal tract of Bewdley Forest.

At the Menith Wood pits, near Pensax, the shafts are from fifty to sixty yards deep, and pass through a considerable thickness of sandstone, having a northerly dip. Two beds of coal, of two feet each, and separated by only two feet of clods, are wrought, and are evidently the same which occur at the foot of the Abberley Hills. A lower and half-yard coal is not worked, owing to its exceedingly bad quality. The dip in Menith Wood is northerly. The overlying coal sandstone is exhibited in fine quarries at Pensax, and is a good building material; but it thins out towards the Abberley Hills, where the overlying strata are composed chiefly of clunch and shale.

There is little else worthy of notice respecting the southerly portion of these coal measures, except that the faults by which they are affected, increase on approaching the trap rocks of the Abberley Hills, and that the strata have there been so completely *inverted* that they appear to dip beneath the older formations, a phenomenon which will be subsequently explained (Pl. 36. figs. 1. to 3.)

The coal which was extracted on the western slopes of Woodbury Hill, and south of the Hundred house, consisted merely of thin shreds of carboniferous strata, thrown up in elevated positions, or rather squeezed up in separate patches between the trap and Silurian rocks (Pl. 36. fig. 2.) These poor and shallow deposits were necessarily soon exhausted, and no accurate records of the works remain.

Similar patches of coal were wrought on the western side of Barrow Hill, and it is said also near Old Storridge Hill[1].

From the preceding details, it appears that no portion of the broken carboniferous tract, extending from Bridgenorth to the Abberley Hills, has ever afforded seams of coal profitable to any extent, although numberless trials have been made over almost every part of its surface. The coal, it is true, is still partially extracted, and can be advantageously used in the burning of lime. From its sulphureous properties, it is also preferred to coal of the sweetest and best quality, in the drying of hops, for which purpose it is much used on the south-western frontier of the coal tract; but throughout the whole of the region described, it is little employed for household or manufacturing purposes. The extreme thinness of the whole formation is most clearly exhibited at many points, where it forms narrow zones between promontories of Old and New Red Sandstone, or where it rests, as at the Abberley Hills, upon the edges of the Silurian rocks: in such situations it would evidently be hopeless to undertake mining operations of any sort. In other parts of the field, particularly to the north-west of Kinlet and between that place and Billingsley, the strata are so disturbed, and

[1] In the first of these cases the refuse of the old pits is still to be seen. In the second, my information has been derived from the testimony of Mr. Jabez Allies of Worcester.

in some parts so perforated by upcasts of the underlying Old Red Sandstone or intrusions of trap, that no geologist would think of there resuming mining operations. Again, the fine section exhibited on the right bank of the Severn, of the carboniferous sandstones which compose the greater part of the Forest of Wyre, as well as the deep natural openings in the forest, prove that the district cannot contain any valuable seams of coal.

With respect to the connexion of the carboniferous strata with the overlying and subjacent red sandstone, it is necessary to say a few words to prevent a casual visitor from mistaking the true nature of these different deposits. In those situations where the Old Red Sandstone, with its associated cornstones, rises up in knolls through the coal measures, the appearances are so fallacious that they might induce unpractised observers to suppose, that these older rocks were truly *included* in the carboniferous deposits, particularly as calcareous concretions very similar to that of the Old Red occur at intervals, both in the overlying lower New Red, and in the upper coal measures. The true cornstones of the Old Red, as will be explained in a subsequent chapter, are usually to be distinguished from those of the other deposits, by the associated strata of red rock, which are generally harder, thinner bedded, and in other respects dissimilar to those of the Newer Red Sandstone; whilst, wherever the Old Red Sandstone underlies or rises *from beneath*, as along the western boundary of the coal-field, there can be no mistake. There are, however, anomalous lithological appearances in some of the rocks which flank these coal-fields on the west of Kinlet; for example, at Prescot Wood and Oreton, where the strata of Old Red Sandstone, though clearly passing *beneath* the carboniferous limestone, put on so completely the lithological characters of coal sandstones, that I am persuaded no one could have disentangled the subject of its apparent intricacy, who had not worked consistently and for a long time over a large area of the surrounding formations[1]. Again, the deep red ferruginous clods of some parts of these coal measures (the "horse-flesh" beds of the Clee Hills) are not very dissimilar in mineral structure from the red argillaceous marls of the Old Red Sandstone.

Like the coal-fields of the plain of Shrewsbury, and those patches south of Broseley, this tract contains subordinate strata of calcareous matter, and passes up as already stated in certain parts into the Lower New Red Sandstone, p. 60; but as yet I have not discovered any animal remains to enable me to speculate on the probable condition of the waters under which these accumulations were formed. Vegetable impressions are numerous, and are found not only in the shale or roof of the coal, but in the district east of Cleobury Mortimer, they are of frequent occurrence in the sandstones.

[1] See an account of these yellow sandstones of the Old Red Sandstone in the fourteenth chapter. Similar varieties of the Old Red will also be described in the Chapter upon Pembrokeshire.

## *Trap Rocks in and adjacent to the Forest of Wyre.*

*Trap of Kinlet.*—The trap of Kinlet, like that of the Clee Hills, has been intruded amid dislocated coal measures, but in this case there is not the same clear proof of its overlying the strata, though it occupies some of the highest knolls. This trap is a greenstone, in which white spots of granular felspar are dotted through a base of dark hornblende, and is therefore dissimilar in structure from the trap of the Clee Hills. The precise relations of this rock are little known, because it occurs chiefly in the beautiful demesne of Mr. Child, where the subsoil has been only slightly disturbed. Recently, however, a considerable face of it has been exposed in a copse west of Kinlet house, and it is there arranged in rude prismatic columns. The ravines on the sides of this park exhibit sections of carboniferous sandstone and shale almost surrounded by protruded masses of Old Red Sandstone, forced up, probably, by the same volcanic action which ejected the basalt on the top of the Kinlet Hills. Besides their convulsed condition, wherever they approach the trap, the strata afford another convincing proof of the posterior intrusion of the latter. On the slopes of this trap the sandstone has a highly altered character, being almost in the state of quartz rock[1]. As this indurated sandstone lies in a highly inclined position close to the greenstone, there can be little doubt that the change of structure has resulted from the action of heat.

*Trap of Arley and Shatterford (left bank of the Severn).*—This is another outburst of trap rock through the same coal measures, the village of Arley being distant only about four miles from that of Kinlet. In this case the trap forms a dyke, which has a main direction from south-west to north-east for a distance of about two miles and a half, viz. from near the left bank of the Severn at Worrel's Mill to Coldridge Wood, north-east of Shatterford, and is then deflected north-north-east to Arley Wood. At Shatterford the dyke traverses the high road from Kidderminster to Bridgenorth. The predominant character of the rock is a light green, finish-grained and highly crystalline greenstone, the hornblende for the most part predominating over the felspar. In some parts it approaches in character to the trap of Kinlet, and in others is not unlike varieties of the greenstone and basaltic greenstone which is intruded into the coal series of Coal Brook Dale. This dyke rises to the surface only here and there. To the west of the high road near Shatterford a small coal shaft has been sunk within a few paces of the dyke. On the wall of the dyke exposed by this shaft is a *sahlbande* of slaty greenstone, in contact with which, the shale is compact and hard, resembling a lydian stone, while the sandstone beyond it is also much indurated; these with the succeeding beds of

[1] It is called "White Jewstone" by the country people, in contradistinction to the "Black Jewstone," or basalt. The rock of Kinlet has been long used as the best road-stone of the adjoining country, and is brought chiefly on the backs of asses from the summits and sides of the hillocks west of Kinlet Hall, where it is always to be found in loose lumps and blocks, but is now wrought at the quarry before mentioned.

[2] See observations on this head in the chapter upon the Caradoc trap.

clod and coal smut, and a thin bed of coal, being all in nearly vertical positions. In following this trap dyke from the Shatterford Gate to Coldridge Wood, we perceive irregular alternations of coal smut, shale, and grit, with protuberances of greenstone, some of which are largely quarried. An opening made in 1833, displayed the injection of the trap into the strata. At the lower end of the quarry were fragments of coal and greenstone confusedly mixed; then followed in overlying succession, yellow clay and clod, terminated by a thin zone of coal smut; next a broad mass of trap, having a tendency to prismatic structure, the prisms being chiefly pentagonal. On the other side of this trap was a bed composed of irregular patches of coal, confusedly mingled with layers of clod, grit, and yellow shale, folding over the irregular surface of the trap. This narrow and broken band was again overlaid by basaltic greenstone, of a rude prismatic form, and of concretionary structure; and this mass threw off finally poor coal seams, dipping 80° to the north-west. Future geologists examining this spot, when the trap or hard road-stone has been extracted, may find the appearances very different from those described; for new phenomena are daily laid open in the quarries, the pickaxe destroying today what it revealed yesterday.

*Red and Porphyritic Felspathic Trap.* (*Church Hill, Stagbury Hill, Warshill.*)

By reference to the Map it will be seen that three other spots in this tract are occupied by trap rocks. The largest of these lies at Church Hill, three miles south-east of Cleobury, where the trap rising to a height of nearly 1000 feet is flanked on three sides by poor coal seams, and on a fourth by Old Red Sandstone. The next in magnitude is Stagbury Hill, situated on the right bank of the Severn below Bewdley, at the south-eastern termination of the coal tract, and marking a point where the New and Old Red Sandstones are in juxtaposition. The third is at Warshill, on the left bank of the Severn, above Bewdley, where a small tongue of poor carboniferous strata stretches eastward, between the New and Old Red Sandstones, which beyond it are again conterminous, as at Stagbury. These hills are all of conical forms, and the trap of which they consist is of a peculiar nature, and very unlike any rock previously described. This rock, in fact, is similar in composition to the trap of the Abberley Hills, which bound this coal-field on the south, and to that of the Clent Hills, which skirt the southern end of the Dudley field, consisting of compact felspar of dingy red and purple colours, and having often a quartzose aspect, somewhat resembling the *cornéen* of French mineralogists.

From this state of compact felspar, this rock passes into other varieties, sometimes porphyritic, but more frequently of a very fine concretionary structure. Like the trap hills of Abberley and Clent, these detached masses present a surface composed of only shivered *angular* fragments, occasionally two feet square; and though excavations have been made to the depth of thirty and forty feet, no solid body of the rock has ever been attained. We can, however, have no hesitation in referring these hills to a trappean

or volcanic origin, since every part of their surface exposes nothing but fragments of the same substances; and as none of these fragments have the slightest appearance of having been transported, but preserve the utmost sharpness and angularity of form, there is no doubt that they have resulted from the rock having a natural tendency to break into such forms. Occasionally, indeed, the fragments have been re-cemented into a sort of coarse superficial breccia (exclusively trappean), of which a good example is to be seen in one of the narrow ravines on the eastern and wooded flank of Stagbury Hill. The coal-measure strata in the vicinity of these hills being highly dislocated, it would appear that the trap of which they are composed must have been erupted after the consolidation of the carboniferous deposits. Again, as fragments of the same trap often form a part of the central members of the New Red Sandstone, it is clear that the eruption in question must have taken place as alluded to in the sixth chapter, either towards the close of the one epoch, or in the commencement of the other; and thus we obtain geological limits for the date of these eruptions.

Having described the various intrusive rocks of this tract, let us consider for a moment the general relations of the deposits of the Forest of Wyre, and then take a short review of the principal phenomena in the Salopian coal-fields of this vicinity.

The strata of the Forest of Wyre cannot be considered as forming different basins, but simply as carbonaceous masses which were originally deposited upon an unequal surface of Old Red Sandstone, without the interposition of the carboniferous limestone. Since that period, the strata having been penetrated at many points by rocks of volcanic origin, the whole country underwent numberless convulsions, by which the former relations of these deposits have been much modified, and their beds thrown into unconnected patches. From what has already been stated, the reader may doubtless have inferred, that this and the other Salopian coal-fields are well exposed only in the contiguity of certain eruptive rocks, and that as they dip in many places beneath the Lower New Red Sandstone, vast carbonaceous deposits may now lie concealed by that formation in positions where they have not been thrown up by volcanic action. Other decisive proofs of this arrangement of the strata, so important to the future development of our national mineral resources, will be brought forward in the chapter on the great Staffordshire coal-field.

Independent, however, of the phenomena resulting from igneous action and disturbance, the following data have been established in respect to these Salopian coal-fields:—

1st. The proof of a younger zone of coal passing upwards, and conformably into the lower members of the New Red Sandstone, and containing within it a peculiar freshwater limestone, always occupying in a long course the same position.

2ndly. The Coal Brook Dale field has been shown to contain, not only this upper carbonaceous zone, but further a full development of the older coal strata, charged with a mixture of freshwater, terrestrial, and marine remains, indicating an estuary origin.

These beds, however, pass down in two localities, into bands of true mountain limestone, containing exclusively fossils of marine origin.

3rdly. The Clee Hill coal-fields consist of only the lower carbonaceous masses, reposing upon millstone grit and carboniferous limestone. These, therefore, were probably accumulated in a bay of the sea. (See Map, next Chapter.)

4thly. In the northern extremity of the Forest of Wyre, where the passage upwards into the New Red Sandstone is clearly marked, no volcanic eruptions having there burst forth to obscure the succession of the stratified deposits, a large portion of carbonaceous masses is thus proved to belong to the younger zone of coal measures; but the order of succession beneath them is not complete, for the carboniferous limestone being absent, the coal reposes directly upon the Old Red Sandstone or Silurian rocks.

5thly. The fields of Shrewsbury and Coal Brook Dale were originally deposited upon rocks of all ages, from the slates of the Cambrian system to the carboniferous limestone included, the latter case being the exception and not the rule, as in other parts of England.

Lastly. Wherever the carboniferous limestone is interpolated between the bottom coal grits and the Old Red Sandstone, it is invariably perceived to thin out in a small range of horizontal extension. This disappearance of the limestone is not occasioned by faults and subsidences, but in all cases, whether at Lilleshall, Steeraway, Oreton, or on the south of the Clee Hills, it can be traced tapering away from a central mass to thin extremities, which really *wedge out* between the coal grits and the older deposits. Since, therefore, we have the clearest testimony that it has been deposited only at wide intervals and in small quantities, it is obviously unnecessary to call in the aid of convulsions, to account for its absence.

These phenomena are in perfect accordance with the views already partially exposed, of the probable distribution of land and sea during the formation of the Salopian coal-fields, great part of which were doubtless accumulated in lakes and brackish estuaries, the occurrence of deep marine bays occupied by pure salt water (in which alone the animals of the carboniferous limestone could have lived,) having been of rarer occurrence in this region. A more complete elucidation, however, of these phenomena will be found at the conclusion of the next chapter.

# CHAPTER XI.

## CARBONIFEROUS SYSTEM (*continued*).

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*Coal-field of Oswestry (North Welsh Coal-field), including Coal Measures, Millstone Grit, and Carboniferous Limestone.—Concluding Observations on the Origin of the Salopian Coal-fields.*

### *On the Coal-field of Oswestry.*

ALTHOUGH this coal-field is in Shropshire, it is quite distinct from the other carboniferous tracts of that county, described in the previous chapters, and constitutes in reality the natural southern termination of the *great coal-field of North Wales*.

The carboniferous deposits with which it is connected, extend by Chirk and Ruabon, expand into the rich coal-field of Flintshire, and everywhere repose upon a thick girdle of carboniferous limestone which separates them from the older rocks of the Principality[1]. Productive coal measures are only developed at certain spots along this zone. The following brief sketch of the little field of Oswestry is given because it lies within the geographical boundary of the annexed map; the Silurian rocks of Montgomeryshire being here terminated, and their edges overlaid by the strata of the carboniferous system. In this, as in other coal tracts, the strata will be described in descending order. (See Map and Section, Pl. 30. fig. 14.)

*Productive Coal Measures* (*b.* of coloured Section, Pl. 30. fig. 14.).—The portion of the Oswestry field which is productive of coal is very limited, occupying a small area between the town of Oswestry and the hills of Llanvorda, Trefonen, Treflach, and Sweeny. It contains only two seams of coal worthy of extraction, the upper being four feet thick and of tolerably good quality; the lower six feet is of comparatively

[1] The full description of the other parts of this calcareous zone and the overlying coal measures will probably be published by Professor Sedgwick, who has investigated that part of the country, so interesting from the complexity of its derangements and the great wealth of some of its metallic veins.

little value. Near their outcrop these seams are separated from each other by about twelve yards of strata composed of shale and clod, with thin courses of sandstone. The roof of the coal abounds in impressions of plants. The coal has, however, been long ago exhausted in such situations, as, for example, in the hills of Treflach, where the millstone grit rises from beneath it, but shafts were more recently at work in the lower grounds between that place and the town of Oswestry, principally on the sides of the depression in which the river Mwrda flows. The poor quality of these coal seams is the chief reason why they have been wrought to so little profit, but other causes of failure have arisen from the very dislocated nature of the strata, and the difficulties attending the drainage of the pits.

The coal having been exhausted, and the works failing near the basset, trials have recently been made much further on the dip, and the coal has been won in two shafts, both of which passed through a thick cover of the Lower New Red Sandstone before the slightest indication of carbonaceous matter was met with. One of these shafts is at the Drillt, on the west side of the road from Oswestry to Llanymynech. The other is on the east side of the same road, and on the grounds of Mr. Parker of Sweeny Hall[1]. As both these works were commenced during my visits to this country, I had an opportunity of examining the overlying strata as they were thrown up around the pit mouths, and they consisted exclusively of different varieties of red and spotted sandstone and shale, quite undistinguishable from the ordinary beds of the Lower New Red Sandstone, which has been so fully described in the fourth chapter. No exact record has been preserved of the section of these beds at the first-mentioned pit, but at the new shaft on the Sweeny Hall estate, the following was the order. The thickness of the overlying red rock was less at the Drillt pit.

| | | yds. | ft. | in. |
|---|---|---|---|---|
| *a.* Soil and embankment | superficial detritus. | 4 | 0 | 0 |
| *b.* Gravel | | 1 | 0 | 0 |
| *c.* Loam, strong clay, and delf. | | 7 | 0 | 0 |
| *d.* Red clunch | | 4 | 2 | 0 |
| *e.* Red bind | | 12 | 1 | 0 |
| *f.* Soft sandstone | | 0 | 1 | 6 |
| *g.* Red bind | | 11 | 1 | 6 |
| *h.* Red clunch | | 12 | 0 | 0 |
| *i.* Hard grey sandstone | | 1 | 0 | 0 |
| *j.* Red bind | | 5 | 1 | 6 |
| *k.* Red clunch | | 5 | 1 | 6 |
| *l.* Red bind | | 3 | 1 | 6 |
| *m.* Brown bind with ironstone | | 5 | 1 | 6 |
| *n.* Red bind | | 5 | 0 | 0 |
| *o.* Red clunch | | 1 | 0 | 0 |
| *p.* Brown bind with seams of sandstone | | 3 | 0 | 0 |
| *q.* Greenish sandstone | | 3 | 2 | 0 |
| *r.* Strong red bind | | 4 | 1 | 0 |
| *s.* Red, greenish and white fine-grained sandstone; *t.* Red, greenish, and grey hard sandstone | | 2 | 1 | 0 |
| *u.* Red sand rock | | 2 | 1 | 6 |
| *v.* Brown clunch | | 3 | 0 | 6 |
| *w.* Red mixed clunch | | 1 | 1 | 0 |
| *x.* Red mixed rock and clunch alternating | | 18 | 0 | 0 |
| *y.* Shale and faint traces of coal | | 0 | 0 | 0 |
| Total thickness of overlying New Red Sandstone | | 118 | 1 | 0 |

[1] These examinations were made when on a visit to my friend Mr. Parker, of Sweeny Hall, to whom I am very much indebted for facilitating my inquiries in the neighbourhood of Oswestry.

Beneath these overlying beds the shaft at the Drillt traverses the coal measures as detailed in this section.

*Section at the Drillt Coal Works.*

| | yds. | ft. | in. |
|---|---|---|---|
| 1. Hard rock bind, with black impressions of plants (crows-feet of the miners) | 1 | 1 | 0 |
| 2. Coaly stuff | 0 | 1 | 0 |
| 3. Grey clunch with "hemp-seed" stone | 2 | 0 | 9 |
| 4. Hard grey grits in parts pebbly, with coal and impressions of plants | 3 | 0 | 0 |
| 5. Dark rock bind (shale) | 0 | 2 | 4 |
| 6. Ironstone | 0 | 0 | 6 |
| 7. Black shale bind | 0 | 2 | 4 |
| 8. Grey clunch | 1 | 0 | 0 |
| 9. Red clunch | 4 | 0 | 0 |
| 10. Mushy or coaly shale | 0 | 2 | 2 |
| 11. Coal | 0 | 0 | 6 |
| 12. Fine stone, with black impressions of plants mixed with pyrites, very hard on the top, passes down into a white rock | 2 | 1 | 0 |
| 13. Black close-grained stone bind | 0 | 0 | 10 |
| 14. Black ironstone | 0 | 1 | 0 |
| 15. Dark bind | 0 | 0 | 1 |
| 16. Coal | 0 | 0 | 1 |
| 17. Dark shaly bind | 0 | 1 | 4 |
| 18. White bind | 4 | 0 | 9 |
| 19. Blue bind | 0 | 2 | 9 |
| 20. Shale and Coal | 0 | 0 | 3 |
| 21. Clunch | 1 | 1 | 0 |
| 22. Blue bind | 1 | 0 | 0 |
| 23. Black clunch | 0 | 0 | 8 |
| 24. Blue bind with ironstone concretions | 1 | 0 | 6 |
| 25. Grey clunch | 1 | 1 | 10 |
| 26. Black shaly mush (impure coal) | 0 | 0 | 6 |
| 27. Grey clod or ricking | 0 | 0 | 8 |
| 28. Black shaly mush (impure coal) | 0 | 0 | 6 |
| 29. Grey clod | 0 | 0 | 8 |
| 30. Coal | 0 | 0 | 6 |
| 31. Clod | 0 | 0 | 8 |
| 32. Coals | 0 | 0 | 6 |
| 33. Grey clunch | 1 | 0 | 0 |
| 34. White bind | 0 | 2 | 10 |
| 35. Black bind | 0 | 0 | 8 |
| 36. Coal | 0 | 2 | 3 |
| 37. Black glossy shale with two beds of ironstone of four inches near the bottom | 4 | 1 | 0 |
| 38. Coal mixed with shale | 3 | 0 | 3 |
| 39. Hard grey clunch with ironstone | 2 | 0 | 0 |
| 40. Broad flaky bind | 3 | 0 | 0 |
| 41. Bind and sandstone mixed with ironstone | 2 | 0 | 0 |
| 42. Strong dark blue bind with plants and ironstone | 3 | 0 | 0 |
| 43. *Coal* | 1 | 0 | 4 |
| 44. Pricking | 0 | 0 | 5 |
| 45. Fine clunch or fire clay | 1 | 1 | 0 |
| 46. Clunch mixed with ironstone | 1 | 0 | 7 |
| 47. Strong brown bind | 3 | 0 | 0 |
| 48. Bind, full of plants | 1 | 1 | 0 |
| 49. *Coal* | 1 | 0 | 0 |
| Total of underlying coal measures | 64 | 0 | 5 |

The two coal beds printed in italics are in use. They are both thinner here than at the old pits, particularly the lower coal, which from six feet near the outcrop, has thinned away to three feet upon the dip.

The other and newest shaft section, though differing in some respects, agrees in all essential points, and it is therefore unnecessary to load these pages with the details. Further observations respecting the probable extension and value of these seams of coal, will be found at the end of the account of this field, the lower rocks of which, or those unproductive of coal, we first proceed to consider.

*Millstone Grit and Sandstone.* (*c*, *d* and *e* of section, Pl. 30. fig. 14.).—The rocks composing this formation are very largely developed in the environs of Oswestry, rising into broad ledges between the productive coal-field and the higher hills of limestone, from whence they sweep down to the lower country in the promontory of Sweeny Mountain on the east, and in the hills of Oswestry racecourse on the west, thus folding

round the productive coal-field, and reducing it to the small embayed area indicated in the Map. In most of these situations the strata of which they are composed, dip at very slight angles beneath the coal, but in the hills of Mynidd Myfwr, and on Oswestry racecourse, the beds are highly inclined. From Sweeny Mountain the same strata advance in low hills to the edge of the great plain of Shropshire, and exhibit the following succession in descending order.

1st. Light-coloured siliceous sandstone, containing a stratum some feet thick, of a porous rock made up of fragments of chert, imbedded in a matrix of fine, white clay, or decomposed felspar and silex (kaolin). This bed resembles that which occurs on a larger scale in the north-western prolongation of these carboniferous tracts at Halkin in Flintshire[1]. It is here underlaid by whitish or pinkish sandstones, sometimes freckled with spots of decomposing oxide of iron: other and lower beds forming the summit of Sweeny Mountain are coarser, containing distinct pebbles of quartz. The finer varieties of these siliceous sandstones, whether of whitish pink or deep red colours, afford excellent building-stones, and are capable of being wrought into the ornamental parts of architecture. (See the recent restorations of Oswestry church.)

This millstone grit, with its light-coloured and whitish building-stone, ranges over the grounds of Porkington, rising up in large masses to Sallattyn Mountain, where it rests upon the limestone. Towards the bottom of the formation, these sandstones become partially calcareous and present a honeycombed aspect, due to the unequal disintegration of their surface. Occasionally the rock may even be termed a sandy limestone (*d.* of section). Fragments of encrinites and corals are also found in these beds, announcing their approach to the calcareous masses beneath. Such masses of calcareous red sandstone are seen also at Pont y Cefn, occupying a broad zone between the limestone and the productive coal-field. They are, however, completely separated from the underlying limestone by a very thick development of pure sandstone, often of a deep red colour, and they may therefore be considered as subordinate to the millstone grit. The red sandstone, or lowest member of the formation, is well exposed to the east of Sweeny Mountain, resting directly upon the great carboniferous limestone, in which position the red rock has the thick-bedded structure, and exact appearance of many varieties of the New Red Sandstone, thus affording one of the numberless examples which will be found in this work of the impracticability of defining the age of strata by mere lithological aspect (*e.* of section)[2].

[1] In Mr. A. Aikin's manuscript notes, I perceive that he describes this bed in other parts as being composed of *knots* and reniform concretions of chert, and the white matter as fine granular silex. The Rev. J. Yates has also given a good lithological description of these grits, though he is in error respecting the geological position or age of these rocks, which he supposed to form a part of the New Red Sandstone of Shropshire. (Geol. Trans., vol. ii. New Series, p. 240.) He describes some of these upper beds as containing hornstone, passing into perfect flint, and he further gives an account of the succession of strata downwards to the limestone, showing at Mynidd Moel how the passage from the one group into the other is effected through a bed composed of grains and small pebbles of quartz and slate, joints of encrinites, &c.

[2] I am informed by Mr. Bowman of Gresford, near Wrexham, that the millstone grit of the Hope Mountain

As the red variety of the millstone grit to the east of Sweeny is in juxtaposition with the Lower *New* Red Sandstone, the exact line of demarcation between the two formations becomes difficult, particularly where the surface of the lower grounds is much encumbered by detritus. The *apparent* similarity of the red rock of the millstone grit to that of the Lower New Red being likely to mislead speculators who do not comprehend the structure of the district, I would therefore repeat, that the first-mentioned rock distinctly *underlies the coal measures*, and reposes on the limestone, and hence that any effort to seek for coal beneath it would be absurd.

### *Carboniferous Limestone* (*f.* of section).

The limestone of this tract (generally known as the limestone of Llanymynech) is by far the finest example of the formation in Shropshire, and extending on the slopes of the higher hills into Denbighshire and Flintshire, it may be well entitled to the old name of "mountain limestone." It is to be observed, however, that even in this range, the limestone is never of such dimensions as to form of itself a mountain mass, for where it attains the height of fourteen and fifteen hundred feet above the sea, it is nothing more than a band, resting upon the older Silurian rocks, which in reality form the chief body of the mountains. (See Sect. Pl. 30. fig. 14.) At a moderate computation, including the impure strata, it has however a maximum thickness of at least four or five hundred feet. It is thrown into ridges rising from beneath each other, and broken through by many transverse fissures, some of which amount to valley gorges. At Llanymynech the limestone presents a bluff escarpment resting on highly inclined edges of Silurian schists, and dipping away at moderate angles. After ranging from Llanymynech to the north-north-east, it is deflected to the north-west, passing by Porth-y-wain to Treflach wood and Trefonen[1]. Thence it is thrown still further westwards by the Carneddew, from which place to Pen Coed y Gaer, it is flanked by a ridge consisting of porphyritic trap rock, and schists and sandstones of the Silurian System. At the point called Sir Watkin's Tower, 1200 feet high, the limestone appears within one hundred yards of the trap rock of Pen Coed y Gaer. It thence trends to the north-east in a bold rocky escarpment called the Craig y Rhiw, passing at Llawn the road from Llanarmmon to Oswestry. It is then lost for a short space, but again

south of Mold, contains strata of the intermediate characters described near Oswestry, some of "the bastard limestones having quartz pebbles bedded in a calcareous cement." In the Bristol district strata of this age are classed as upper limestone shale by Buckland and Conybeare.

[1] The Ordnance map of these parts not being published when my last visit took place (1836), I could not accurately define these breaks, and if my readers find this portion of the accompanying map the least accurate in the delineation of the outline, they must attribute it to the want of that invaluable assistant to the field geologist, an accurate survey, without which indeed the map accompanying this work could never have been undertaken. The trap rocks are indicated on the map, but I shall not particularly describe them on this occasion, as I could not discover them in absolute contact with any member of the Carboniferous System.

appears, proceeding in a northerly direction at Orsedd-wen[1] on the higher part of the Sallattyn Hill, 1300 feet above the sea, and is worked on each side of the little stream at Craig-nant five miles north-west of Oswestry[2]. From Craig-nant its course is north-north-east by Bronyarth and Vron-frian, passing to the west of Chirk, whence it is more or less continuous along the edge of the carboniferous tracts of North Wales. In this range the inclination of the strata varies from 5° to 45°, and they everywhere dip beneath the millstone grit. Some of the upper members of the limestone at Llanymynech are of yellowish and reddish colours, and are more or less charged with magnesia, and have occasionally cells containing crystals of pearl spar.

These beds pass down into the great body of the limestone, which is subcrystalline, and of excellent quality. In the lofty vertical face of the quarries at Llanymynech, one of the principal beds, called "the Upper Red," has a thickness of twenty feet without a divisional way-board; beneath this are certain yellowish impure beds called "Delf," probably containing magnesia: the lowest stratum in work is of a grey colour, and so veined and mottled with deep red, that it is known as the "bloody red bed." The whole succession of the strata cannot be seen in any one escarpment, and the lithological characters vary so very much in the different ridges above alluded to, that the description of the yellowish upper beds near Llanymynech would little agree with the dark grey beds with shale at Trefonen, though the latter are also upper beds. The best section, however, of the lowest beds with which I am acquainted is at Craig-nant, five miles west of Oswestry. The thick or central masses of pure limestone are there seen passing down into dark brown and yellowish, impure, sandy limestone and chert, alternating in thin beds with dark-coloured shale. These beds, called "malk" by the workmen, represent the lower limestone strata, and they rest unconformably on Silurian Rocks.

It may be here remarked, that like other solid rocks hereafter to be described, this limestone is in most parts symmetrically divided by a number of joints, some of which are vertical; others vary in their inclination, but usually their planes form right angles with the surfaces of the beds. The greater number of these joints run in directions diagonal to the strike, though some proceed directly in the lines of the dip, and others coincide with the strike; but whatever these relations may be, they invariably change with each variation in the direction of the mass of rock examined. (See observations on joints in a subsequent chapter on the Silurian Rocks in the environs of Ludlow.)

At Llanymynech the limestone was in ancient times the seat of mines, as is proved by the galleries attributed to the Romans; but now there are few indications of any metallic veins worthy of notice, although the sides of the joints are occasionally tinged green by carbonate of copper.

In a range of low hills north of Llanymynech, and near the canal, some of the upper beds, consisting of reddish and yellowish hard limestone, contain thin veins of green and grey carbonate of copper, running transverse and diagonally to the general strike of the limestone; but though trials have been attempted, no body of ore has been detected. Small veins of lead are said to occur north of Craig-nant.

The prevailing fossils are the large *Productus hemisphæricus, P. Martini,* and other mollusks, with a vast abundance of corals and crinoidea peculiar to the limestone of this age.

[1] *Orsedd-wen:* Angl., The white palace.

[2] At the spot where Mr. West has recently erected a tower to mark the course of Offa's Dyke.

*Faults.*

This tract is affected throughout by a great number of faults, many of which can be studied in the ravines and natural escarpments of limestone, which rise from beneath the coal-field. Thus, great transverse breaks can be observed between the ends of each ridge of limestone, and splendid examples of dislocated masses are exposed in the picturesque cliffs of Craig-y-rhiw, where this rock is in contact with Silurian schists and near to a point of eruptive trap. It is, however, only from the miner that we can obtain a correct knowledge of those faults which have affected the productive coal-field. The Lwynymain or big fault runs north and by east, and south and by west. On the hilly or western side of this fault the coal was worked in the Dog pit, at a depth of *two hundred and twenty yards*, while on the lower or eastern side, the same seams of coal are within *forty yards* of the surface. There is one other principal fault, nearly parallel to the above, which occurs further on the dip, by which the coal strata descending towards the plain, are again heaved up. This is another upcast on the dip, and to an extent of fifty yards. By inspection of the map it will be seen that both these faults are only slightly divergent from the principal strike, or line of elevation of the adjacent mountains on which the coal-field reposes. A third fault, equally an upcast to the east, but diverging considerably from the two above mentioned, occurs close to the western side of the new works on the Drillt: this is a throw of twenty yards. There are many minor faults, but few of these preserve any distinct parallelism to the main faults, or to each other. The phenomena on the sides of these faults, where the ends of the shattered strata have been laid bare, are similar to those observed in other coal-fields, the edges of the strata frequently presenting that polish, known to miners under the name of "*slickensides*." It is unnecessary to give further details respecting these dislocations, and I only solicit attention to the fact, that the main faults run in a direction nearly parallel to the elevated range of sandstone and limestone forming the hills at the back of the coal-field; for as we see that the oldest strata on which these masses repose, have been penetrated by rocks of igneous origin, we may confidently conclude that the forces which elevated the hills, also gave rise to the principal parallel fractures of the adjacent coal measures; and further we observe that the fault of greatest magnitude is nearest to the mountain range, and that as the strata recede from it, the dislocations are of minor extent. Again, the persistence of these north and south faults into Denbighshire is a full confirmation of their dependence on the principal lines of elevation of the adjacent hills, which form the margin of the North Welsh coal-field.

The average dip of the coal measures is about one in six, and this inclination varies little, either on the west or east side of the great faults. The small portion of this coal-field which is now productive, is a trough in the millstone grit between Oswestry and Sweeny, to the north and south of which the coal is fairly thrown out by the rise of that rock. Nor are there just grounds for hoping, that any great mass of coal is prolonged

beneath the Lower New Red Sandstone of the plains north and east of Oswestry, since the beds of coal recently proved at the Drillt beneath that formation, instead of thickening on the dip, have been found to thin out; the upper coal, which was four feet at the Old Works near the outcrop, being only two and three, and the six-feet coal being reduced to three feet. (See Section, Pl. 30. fig. 14.) The inferior quality and thinness of the coal are therefore sufficient to check enterprise; and finally it must be remembered, that this tract is the southern *termination* of a great carbonaceous zone, the richest parts of which are in Flintshire and Denbighshire[1]; and that the coal-bearing strata, *gradually diminishing in size and deteriorating in quality as they pass southward*, are found at Oswestry in the thin and slightly productive condition above described.

[1] Mr. Bowman of Gresford, with the assistance of his friends Mr. Kyrke of Glascoed and Mr. Pickering, has furnished me with a synopsis of the principal coal seams in Flintshire and Denbighshire. At Mostyn there are twelve beds of workable coal in a thickness of about two hundred yards of measures, the uppermost of which is a *cannel* coal eight feet thick, the others varying from one to fifteen feet. At Bagillt, south-east of Holywell, there are five beds, but three only have been worked. At Flint, Coed Talwin, and other places south of Mold, there are three beds only of coal, but this is owing to the rise of the limestone and millstone grit, the upper coal measures having been denuded. Here also the chief coal is fifteen feet thick: south of the Hope mountain, and extending south to Wrexham, the measures on both sides of a great north and south fault contain ten beds of coal, of the following names and dimensions, in descending order:

| | | yds. | ft. | in. |
|---|---|---|---|---|
| *Brymbo and Broughton coals.* | *Lower Drowzey*, or stinking coal | 0 | 2 | 3 |
| | *Small coal*, excellent quality | 0 | 2 | 5 |
| | *Drowsall coal*, excellent quality | 1 | 0 | 0 |
| | *Powch coal*, average quality | 1 | 1 | 0 |
| | *Two-yard coal*, very good | 2 | 0 | 0 |
| | *Crank coal*, hot but not brilliant | 0 | 2 | 3 |
| | *Brassy coal*, excellent for making iron | 1 | 2 | 0 |
| | *Black bed coal* | 0 | 1 | 6 |
| | *Main coal*, of first quality | 4 | 0 | 9 |
| | *Yard coal*, good quality, not much worked | 1 | 0 | 0 |

## *General Reflections on the origin of the Salopian Coal-fields.*

The previous chapters will I trust have convinced the reader, that the various coal-fields of Shropshire have been accumulated under different conditions. That of Shrewsbury, for example, being charged with remains exclusively of terrestrial or freshwater origin, is supposed to have been formed by rivers emptying themselves into lakes; that of Coal Brook Dale, containing a mixture of freshwater and terrestrial with marine remains, is referred to an estuary origin; whilst a third class like the Titterstone Clee, or the Oswestry fields, in which nearly all the animal remains are marine, were probably formed on the shores of an open sea, or in bays of salt water into which plants had been drifted from the adjacent lands.

This view, however, of the former probable condition of the surface of this part of our island, during the accumulation of the carbonaceous deposits, though quite intelligible to geologists, may with difficulty be apprehended by persons unaccustomed to estimate the weight of the evidences on which it is based. For such of my readers therefore I here offer a slight sketch of some of the proofs from which the inferences have been deduced.

The discoveries of modern geographers have shown to what great distances vegetable materials, drifted by streams from the land on which they have grown, are deposited amid silt and sand. The narratives of Franklin and Back, but more particularly that of Richardson, in describing the polar regions, inform us that the rivers are there constantly transporting wood and plants, sometimes heaping them up in the large freshwater lakes and embayed sea openings, which occupy large portions of that continent; at other times sweeping them out to the open sea, and lodging them upon its shores. In the central territories of the same vast continent, we have the testimony of Capt. Basil Hall, that similar accumulations are constantly taking place towards the mouth of the Mississippi; and hence we have every reason to conclude, that all great rivers descending from wooded countries must be daily forming like deposits.

Such existing causes (ample illustrations of which will be found in Lyell's Principles of Geology,) serve therefore as the first link in the chain of evidences; for they explain to us *how* the vegetables from which coal has been formed, may have been carried into their present positions from *adjacent* lands.

The chemist proves, that the ultimate elements of coal are identical with those contained in plants; and that it is in entire accordance with the laws and known phænomena of chemistry, that a new compound such as coal may result from gradual changes among the elements of vegetables. The observations of Hatchett indeed distinctly lead to the opinion, that it is especially the resinous principles of plants which have mainly contributed to the production of coal[1].

Armed therefore with these data, the geologist proceeds to examine the natural phænomena laid open in the various deposits constituting the crust of the globe. Even in the most superficial of these, he finds occasionally some vegetable matter which has partially lost its original properties; in other strata of nearly the same age, these materials appear in that peculiar state of carbonization termed "brown coal"; whilst even in beds younger than our London clay, he perceives that all the vegetable tissue has disappeared, the mass having been transmuted into the black solid and shining mineral we call coal.

With such phænomena before our eyes, it is no wild hypothesis to suppose, that if the transatlantic region alluded to were drained, or, in other words, if the bottoms of the

[1] See also MacCulloch's ingenious observations on the formation of coal out of vegetables. (Geol. Trans., Old Series, vol. ii. p. 1.)

lakes and shores of the sea near the mouths of great rivers were elevated and laid dry, they would present us with a gradation of similar phænomena, from the decaying drift wood recently lodged in the subaqueous surface, to the half-carbonized vegetables, perhaps even down to coal itself, the result of plants having been entombed in mud and sand from the earliest period, when the rivers in question began to flow[1].

Pursuing his investigations in descending order, the inquirer at length finds, that throughout the whole succession of sedimentary strata, there exists the same analogy; and that wherever the beds contain many impressions of plants, coal of one description or other is as constantly associated. Commencing in the tertiary period, when the relations of the land and sea were approaching to their present condition, we have many proofs of similar accumulations. Thus the deep gorges and river valleys which run into the recesses of the Alps, may be cited as clear and well known examples; for in these we find carbonaceous matter piled up in alternating layers of sandstone and shale, (the sand and mud of former days,) on which are impressed the forms of various vegetables. Some of these deposits, containing fluviatile and terrestrial shells, were evidently heaped up by rivers or in lakes; while others, at lower levels on the mountain sides, pass under strata charged with marine remains little differing from those of the present æra. This stage of the inquiry presents to us the surface of the globe in some degree diversified by continents like our own, and hence the plants from which the coal of this period was formed, though differing specifically from recent vegetables, are analogous to them in general aspect. (Dicotyledonous Plants.)

Descending through the upper secondary formations, we recede to periods when all the animals and plants contained in the strata are dissimilar from those of existing nature, but still we have occasional proofs of dry land in terrestrial, lacustrine, and fluviatile accumulations alternating with marine deposits. The freshwater shells and land-plants of the Wealden—the fossil flora of the lower oolitic formations (Yorkshire and Brora), are examples familiar to geologists.

In the portions of the globe hitherto examined, these last-mentioned æras appear on the whole to have been little productive of vegetables, and hence we find the amount of coal in deposits of this age to be small. As far as our present data enable us to speculate, it would appear that the plants of these formations, differing essentially from those above the chalk, have an intertropical character, which some geologists conceive to be a proof of the existence of smaller continents than those of the more modern periods, the lesser degree of cold arising from an insular surface, suiting such a vegetation; but we must not forget that the flora in question has been collected only in Europe, and

[1] See some excellent apposite remarks by Dr. Fitton on other collateral geological features, which the northern part of the continent of America would present, in case it were now sunk beneath the sea, so as to lodge a sheet of marine strata upon the surface of the present terrestrial and freshwater accumulations. (Geol. Trans., vol. iv. p. 325.)

[2] Examples,—Styrian Alps, Gratz, &c. Sedgwick and Murchison, Geol. Trans., vol. iii. p. 301.

strictly speaking, therefore, it can only indicate the probable condition of the climate at and near the spots where the fossil plants were detected.

Lastly, we descend into the ancient carboniferous strata under consideration. Now, as in these the whole fauna and flora are very dissimilar from the animals and plants of the present day,—and even distinct from those of the intermediate periods,—thus affording evidence of having existed during a very remote æra,—so there are abundant proofs, in the nature of the coal and its associated strata, that the substance there accumulated is the result of *gradual molecular changes* among the elements of organic matter, which have been buried during many ages beneath the increasing and varied sediments. The vegetation of this distant epoch, the earliest, as I shall hereafter show, in which the presence of any considerable quantity of terrestrial plants has been yet detected, is said by botanists to bear an exclusively tropical character, or in other words, to prove a moist atmosphere and warm climate; for the large succulent plants, and arborescent ferns which abound in the coal measures, could only have grown to their vast size with much moisture, and an atmosphere so moist could alone be obtained in a hot climate. Hence, though it is manifest from the evidences adduced, that dry land was in existence in the immediate neighbourhood of the coal-fields described, such land consisted probably of nothing more than low insular masses, favouring the production of plants requiring a warm climate. (See the small Map, fig. 2, opposite[1].) This inference is not, however, intended to lead my readers to imagine, that other and larger continents may not have existed at the very same period.

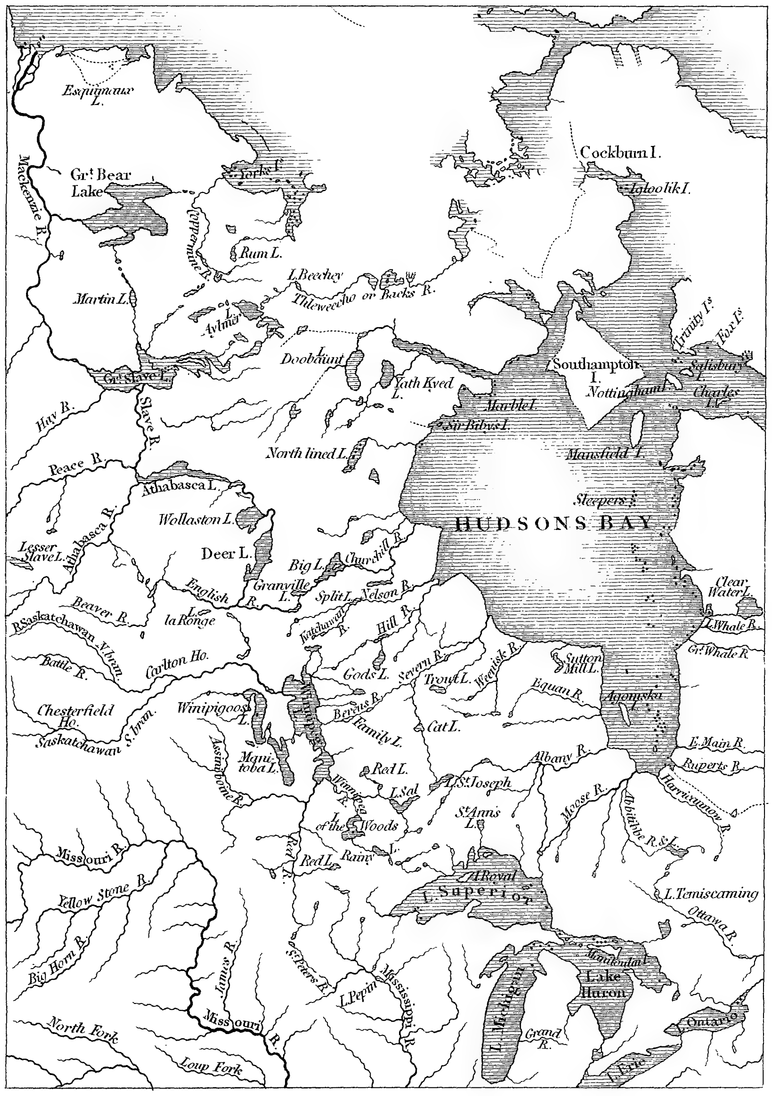
Whether, therefore, we begin our examination at the present surface, and descend from the vegetable deposits lodged in lakes and estuaries, through the tertiary and secondary strata, down to the carboniferous system, or ascend from these old rocks, we meet at successive stages with a regular series of analogous proofs, that vegetables, *differing in their forms in each successive æra,* were drifted from *adjacent* preexisting lands, and have invariably been the materials out of which coal has been elaborated.

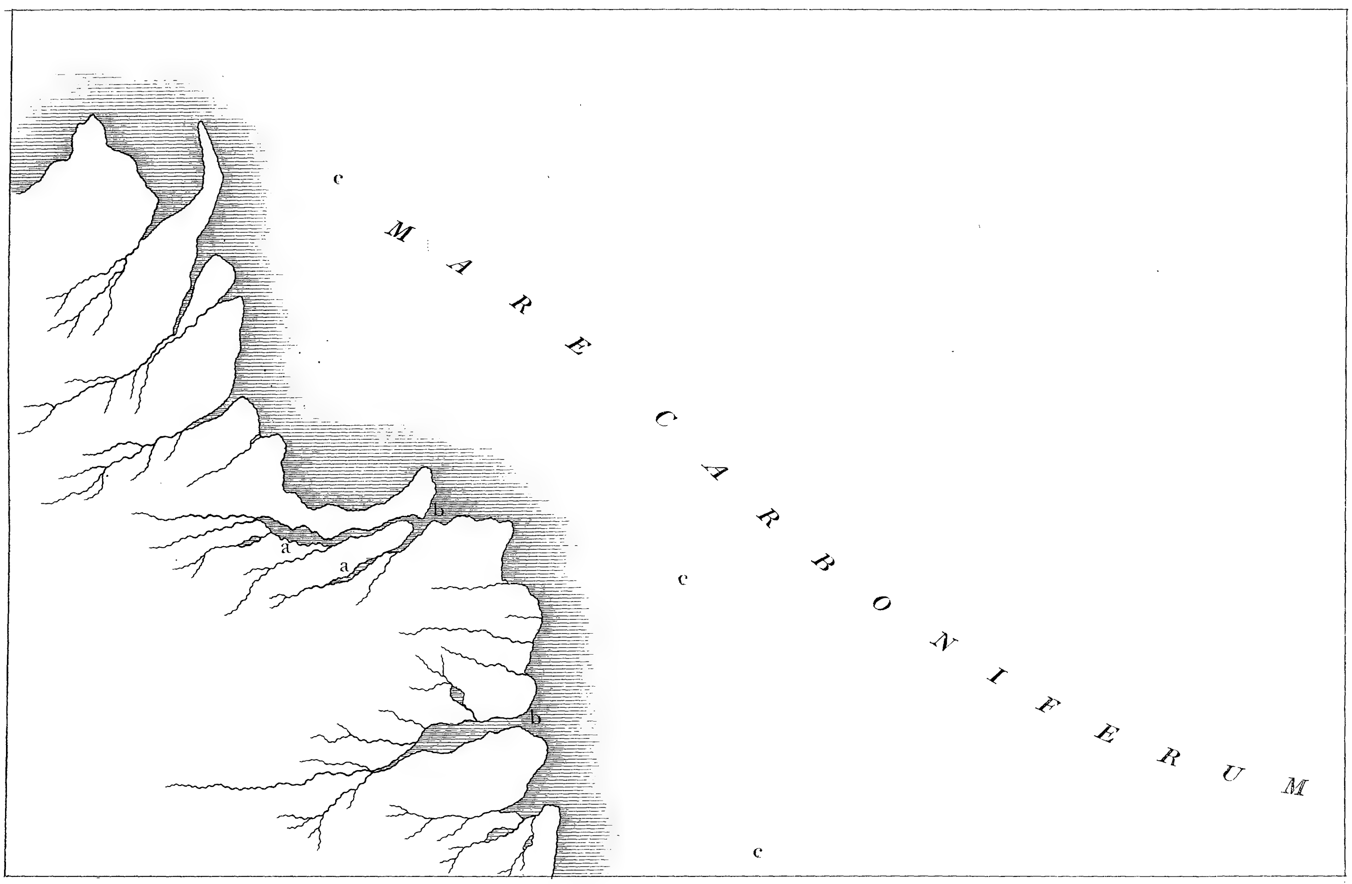
I shall revert to this interesting subject of fossil vegetation, when the rocks of the Silurian system have been described. In the mean time, to illustrate these views, I annex two small maps. The uppermost of these represents, on a very reduced scale, the actual proportions of land and water, in a part of the North American continent before alluded to. This map is intended to explain how the drift wood, accumulating

[1] Many remarkable and convincing proofs of the strong analogy and similarity of the fossil flora of the coal-fields to plants of tropical and intertropical characters, will be found in that beautifully illustrated work of my esteemed friend Mr. Witham, of Lartington Hall, Yorkshire. With the assistance of Mr. Nicol, Mr. Witham has developed the vegetable tissue, by slicing and polishing the stone containing the impressions and forms of the plants. Mr. W. Hutton has subsequently shown by a similar process that the vegetable tissue is occasionally discernible, even in the most compact cone of the Durham and Northumbrian fields. In some of the old coal-fields, the form of the vegetables is actually apparent in the coal itself. Examples of this have been already mentioned, in ill-consolidated coal at Tasley near Bridgenorth, and at the Brown Clee Hills, and other similar cases will be noted in the Dudley coal-field.

in lakes or the sea-shores, may form *future* coal-fields, upon any great changes taking place between the present relative levels of land and water, by which the subaqueous accumulations may be desiccated.

The second is an ideal map representing the probable outline of a part of the region under review, when the carboniferous series *was accumulating*. The Silurian and older rocks are supposed to have been the dry land from which rivers flowed, occasionally lodging the vegetable matter in partial lakes (*a a*), before they discharged their contents either into the estuaries (*b b*), or into the broad sea marked "*mare carboniferum*" (*c c*), under which the largest accumulations of coal previously described, were formed. The area so designated, is that which is *now* covered by the New Red Sandstone of the central counties, from beneath which the coal measures protrude at many points, as detailed in this and other chapters. The reader will thus learn how some beds of coal may be associated with freshwater, and some with æstuary productions, whilst others have been formed amid accumulations exclusively of marine origin.




Engraved by J. Gardner, Regent Street

# CHAPTER XII.

## CARBONIFEROUS SYSTEM (*continued*).

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*Coal-field of Newent.—Carboniferous Limestone of South Wales and Monmouthshire ; and organic remains of the formation.*

### *On the Coal-field of Newent, Gloucestershire.*

QUITTING the region of Shropshire, and passing from the edges of the North Welsh coal-field to those of the great South Welsh basin, let us pause for a few moments by the way, to examine a small carboniferous tract near Newent in Gloucestershire, although its strata are of so little value, as scarcely to entitle them to the appellation of a coal-field. The New Red being here almost everywhere conterminous with the Old Red Sandstone, these coal measures can only be detected rising to the surface in such thin stripes or patches along this junction-line, that it is scarcely possible to indicate them. Wherever they exist, they may in general description, be said to be covered by the New, and to rest upon the Old Red Sandstone. (See Section, Pl. 30. fig. 10.)

At Lower House to the West, and at Boulsdon to the South of Newent, there were formerly coal-pits, but they have been abandoned many years, and the information now to be derived from a few old workmen is scanty and imperfect. At Lower House it appears, that the pits were 50 yards deep, commencing in the New Red Sandstone. The measures dipped about 25° to the N.E., E., and S.E., and were affected by *numerous* faults, the largest of which occasioned athrow of 25 yards. The section passed through

| | feet. |
|---|---|
| New Red Sandstone | 21 |
| Whitish clay | about 100 |
| Hard whitish sandstone with plants | |
| Reddish-brown clunch | |
| Shale, &c. | |
| Coal | 7 |

And beneath this coal were 16 feet composed of shale, with three other seams of coal, viz., 2 feet, 1 foot 6 inches, 1 foot 2 inches ; the lowermost being sulphureous.

In this sinking, the overlying Red Sandstone is said to have partaken of all the flexures of the underlying coal-measures[1]. At Hill House Colliery, a little to the north of Lower House, and

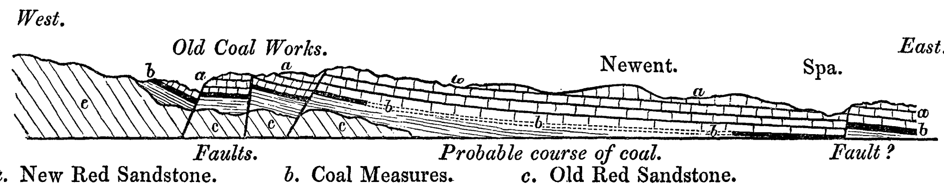
[1] See previous observations on this point, p. 51, &c.

nearer to the outline of the Old Red Sandstone, the coal strata were found to be so highly inclined, that the works were soon abandoned, though not before the ruin of those concerned. At Boulsdon, 6 shafts were opened about 30 years ago by a Joint Stock Company. Here, as at Lower House, there were 4 seams of coal lying nearly all together, the first being 1 foot 6 inches, the second 10 inches, the third 10 inches, and the lowermost 2 feet 6 inches in thickness. The shafts were from 63 to 80 yards deep; the faults were very numerous, and the enterprise was abandoned owing to the great influx of water. The strata inclined slightly to the south, or from the flank of May Hill[1].

Poor as are these coal-seams, it is exceedingly probable that the works were undertaken at those spots along the line of outcrop where the measures are the thickest; for the coal-field actually thins out to the north and south, and these pits were sunk at intermediate points. In the hills north of Newent, indeed, there are instructive examples of the thinning out and final disappearance of the carboniferous strata. A good illustration of this was made apparent when the tunnel of the Ledbury Canal was cut through these hills. A man, 80 years of age, who worked in it, informed me, that midway in the hill, between the soft sandy beds (New Red) on the south, and the stiff clays (argillaceous marls of the Old Red), on the north, they drove through a thin vein of "coaly stuff" with poor thin "pieces" of the mineral, but without, as he termed it, "any state of coal." Following the line of junction of the New and Old Red to the north, I found precisely similar evidences exposed under the escarpments of the New Red Sandstone, extending from the Castle Turnpike to Pit Leases. At various intermediate spots along this line, shafts have been sunk and thin portions of coal extracted; but these are entirely wanting in other places, and the conglomerates of the New Red are actually seen in open quarries resting unconformably on the inclined beds of the Old Red. To the east of Gamage Hall, the carboniferous beds appear for the last time in this direction, the coal itself cropping out in the ditches of the ploughed lands which lie between the rye-land hills of New Red Sandstone, and the clay of the Old Red. The water passing through the porous overlying strata, is held up by the narrow argillaceous zone of coal measures; which is of so cold and heartless a quality as almost to defy improvement. This is the clearest example I am acquainted with, of the thinning out of a coal-field. It was a very interesting task, indeed, to trace the same strata from this narrow wedge near Gamage Hall, through all their contractions and expansions, between the New Red Sandstone and the Old, to their full development in the trough-shaped land to the west of Newent, and again to follow them till they finally disappeared upon the sides of May Hill, where the New Red Sandstone reposes at once on the Old Red Sandstone and Silurian rocks. If coal-works are ever to be resumed near Newent, with any prospect of success, the trials should be made to the east of the town, by sinking through a thicker cover of the

[1] Owing to the condition of the surface resulting from these old works, I could not perceive whether the coal measures at this spot had been covered by any portion of the New Red Sandstone.

New Red Sandstone than any hitherto penetrated; for as it appears that the most important seams on the west, dipped to the east and south-east, so is it possible that the measures may be found to have expanded, when followed upon their dip. Whether this prove to be the case or not, there can be little doubt that these carboniferous strata, in some form or other, are prolonged beneath the New Red Sandstone to the east of Newent, as indicated by a highly sulphureous medicinal spring, which there rises to the surface[1]; whilst there is every probability that the strata being further removed from their junction with the Old Red Sandstone, may run in more continuous and unbroken masses, than in those spots along the line of outcrop, to which all previous undertakings have been confined.



17.

*a.* New Red Sandstone. *b.* Coal Measures. *c.* Old Red Sandstone.

The importance of the discovery of a *really productive* coal-field in this accessible and level tract, is too obvious to require notice, seeing its contiguity to that part of Gloucestershire on the one side, where the overlying formations are of great thickness; and to those wide agricultural tracts of Herefordshire and South Worcestershire on the other, in which, from their geological relations, no coal can ever be detected.

[1] By this observation, I do not mean to imply that sulphureous waters are always to be taken as proofs of the existence of carboniferous strata. (See remarks on Mineral Waters, p. 34.) Here, however, the reasoning would be as follows. The coal measures which crop out on the west, contain much iron pyrites, which on decomposing would afford sulphureous springs; on their dip to the east, these beds pass beneath a cover of New Red Sandstone, in which *no* pyrites is observed, and hence it is fair to infer, that the waters which have flowed upon the inclined and pyritous beds of the coal measures, after becoming highly sulphureous, rise to their original level through cracks in the overlying sandstone. In fact the depression in which the spring rises, is probably the scene of a fault, by which the coal measures are thrown up to the east of this mineral source. (See Wood-cut above.)

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## *Northern, Western, and Eastern edges of the great Coal-basin of South Wales.*

### *Carboniferous Limestone.*

THE value of its mineral contents, and the great extension of the South Welsh coal-basin, entitle it to be treated of in a separate work, and geologists may well rejoice that the task of describing it has been undertaken by the Rev. W. Conybeare. I have, therefore, not attempted to examine in detail any part of this basin, but have confined my observations to that portion of its margin which is conterminous with those ancient

rocks to which this work is more peculiarly devoted. (See Map.) The natural faces of the rocks forming the northern and north-western escarpments of this coal-basin, are indeed of great value in explaining the regular order and succession of the strata between the carboniferous and Silurian Systems, for these sections exhibit a full and unbroken sequence of all the intermediate strata, nothing being left to hypothesis or the imagination. (See Pl. 31. fig. 1.)

The carboniferous limestone of the South Welsh coal-field, as seen in Monmouth, Brecon, and Caermarthen, is on the whole a strong regularly bedded mass, partly light coloured, rarely oolitic, and occasionally of so dark a tint as to be termed "black marble[1]." It is overlaid by the conglomerates and sandstones of the millstone grit or base of the coal-field, and rests upon another conglomerate, very similar to the millstone grit, but generally of a redder colour, which constitutes the uppermost stratum of the Old Red Sandstone. In its course through these counties the limestone occupies the form of a tortuous girdle, conforming to the shattered outline of the coal measures[2].

It is of inconsiderable thickness when compared with the formation of the same age in Yorkshire, Denbighshire, or even in the adjacent parts of Monmouthshire and Gloucestershire, rarely if ever expanding to more than five hundred feet. In that portion of the escarpment which has been the least dislocated, as to the south of Abergavenny, and Crickhowell, the average inclination of the beds is very slight, not exceeding 7° or 8°, and the dip is towards the centre of the coal-basin.

With this feeble development of the chief mass of limestone, the upper and lower limestone shale are also of small dimensions when compared with the same rocks in the northern counties, or in the environs of Bristol, and in the east of Monmouthshire, where we shall soon describe them. Even, however, in the South Welsh coal-basin, the lower limestone shale may be traced as a continuous band along the escarpment, and when hidden from view by herbage or detritus, its place is usually marked by boggy ground, springs, or rivulets, the waters of which, having been absorbed by the porous strata of the overlying coal grits and limestones, are thrown out by this argillaceous band, and fall in rills over the scarped and lofty edges of the Old Red Sandstone. It is not in my power to describe all the varieties in lithological structure, and all the organic remains of the formation in this region; but a few remarks upon an interesting accidental feature are worthy of notice. My attention was called to this circumstance by the Rev. H. Lloyd, who had found detached fragments of this peculiar limestone. The surfaces of the stone present a glazed or varnished appearance, which at first sight I thought might be owing

1 The black limestone or marble is largely developed in Cermarthenshire (Llangyndeyrn, &c.). The Earl of Cawdor's new mansion at Golden Grove, near Llandeilo, is built of it.

2 Some of the most extensive of the dislocations producing this outline are seen to the north-east and north-west of Merthyr Tidvil, where they will be specially described by Mr. Conybeare. The great dislocations in the neighbourhood of the Caermarthenshire Fans, or highest points of South Wales, will be specially explained at the end of this chapter.

to vitrification. On tracing, however, these glazed fragments up the bed of the mountain rivulet near Blaen Cennen, in which they had been found, I discovered their origin to be in a portion of the great escarpment, which having been subjected to a downcast, is for the space of a mile almost submerged in a turf bog, the ends alone of the strata being exposed in the bank of the little stream. (See Map and Pl. 30. fig. 12.) From the unaltered condition of the limestone and shale underlying these glazed beds, it appeared almost certain, that the altered external characters of the upper layers of the rock, could not be due to any cause connected with igneous or gaseous agency acting from beneath; and besides no rock of trappean or volcanic origin occurs in any part of the adjacent tract. Internally, these beds present the usual semi-crystalline structure and grey colour of the limestone, but the varnished coat extends over all the surfaces, including every cavity. The glaze is brittle, yields to the knife, and is colourless and transparent, the veins of calcareous spar and tints of the rock not being hidden by it. As these glazed strata, protruding from beneath a deep peat bog, have an aspect similar to that produced on limestone by very diluted muriatic acid, it has occurred to me that the peculiar condition of the surface might have resulted from long-continued immersion in water, impregnated with the slight vegetable acid of the bog.

Caverns frequently occur in this limestone, and that from which the river Lwchwr suddenly bursts forth is a fine example, analogous to those sources of subterranean streams which are of such frequent occurrence in every country where calcareous rocks abound.

The most prevailing fossils are the

*Productus hemisphæricus*. M. C. t. 328.
——— *Martini*. M. C. t. 318. figs. 2, 3 and 4.
——— *comoïdes*. M. C. t. 329.

together with many prevailing corals of the formation, all of which are dissimilar from any which we shall afterwards describe in the Silurian System. (See detailed list of many of these fossils at the end of this chapter.)

In its course through Caermarthenshire, westward of the great dislocations near the Fans, the zone of limestone maintains a considerable thickness as far as the pass of Llandybie, and at the extensive limeworks of Garn-fach or Calch-gorog, four miles south-east of Llandeilo, I estimated it at not less than three hundred feet. Thence to the flexure which forms the extreme south-western edge of the coal basin, the zone becomes thinner, and the large quarries of Llangyndeyrn, six miles south-east of Caermarthen, are the last spots where it is seen in force; for to the south-west of the Mynidd Garreg, and immediately north of Kidwelly, the rock dwindles to an obscure band, which is no further traceable in the sea cliffs on the left bank of the Towy. By reference to the map it will be perceived, that further to the westward, patches of this carboniferous limestone re-occur on the coast near Laugharne, overlying the Old Red Sandstone in both banks of the River Taaf. Although these patches are in Caermarthenshire, they form

no portion of the girdle which surrounds the great coal basin of South Wales, but are remnants of another large carboniferous tract in Pembrokeshire, to which allusion will be made in a subsequent chapter. The various elevations and subsidences to which the limestone has been subjected, between the Caermarthen Fans and the mouth of the Towy, and the different degrees of inclination at which the strata dip, may be observed in the accompanying maps and sections, and long details respecting them are uncalled for, as they must naturally form a portion of the work of Mr. Conybeare. The dismemberments in the immediate neighbourhood of the Caermarthenshire Fans, with an account of two remarkable outliers, will form the subject of the next chapter.

*Additional observations on the Carboniferous Limestone of Monmouthshire, particularly on the Upper and Lower Limestone Shale.*

Besides the previous brief sketch of the northern, north-eastern, and western portions of the carboniferous limestone of the South Welsh coal basin, there will be found details respecting the development of the formation, in the subsequent chapters upon Pembrokeshire and Tortworth in Gloucestershire, in which, for the sake of clearness, all the strata associated in those tracts are described in succession. But after all, there are many districts occupied by this limestone as laid down in the map, to which little further allusion will be made. Before, however, we enter upon the consideration of the Old Red Sandstone, I must direct attention to those places in Monmouthshire in which there are the best examples of the beds of passage between the limestone and the millstone grit, and through the lower limestone shale into the Old Red Sandstone; as it is particularly with the aid of such examples that general portions of the tabular view have been filled up. The tracts of carboniferous limestone specially adverted to, are those in Gloucestershire and Monmouthshire, which lie between the great South Welsh coal basin on the one side, and the coal-fields of Bristol and Forest of Dean on the other, and occupy the splendid gorges of the Wye near Chepstow. For much valuable information respecting these limestones, I refer the reader to the valuable memoir of Dr. Buckland and Mr. Conybeare on the Bristol coal-field, with which these and other carboniferous rocks of the adjacent districts are placed in parallel.

Of the Upper Limestone shale, however, as seen in the gorge of the Avon at Clifton, I here subjoin an instructive and accurate detailed section by Mr. Lonsdale, made to illustrate a suite of specimens in the Bath Institution, which though never previously printed, appears to me to be of too great value not to be made public.

Lower Grit.

| | ft. | in. |
|---|---|---|
| 1. Rubbly marl | 16 | 0 |
| 2. Highly ferruginous sandstone | 2 | 0 |
| 3. Limestone more or less oolitic | 10 | 0 |
| 4. Rubbly limestone mixed with marl | 8 | 0 |
| 5. Variegated marl | 8 | 0 |
| 6. Oolitic limestone; in the superior part of the bed are small quartz pebbles | 1 | 6 |
| 7. Grit more or less fissile | 5 | 6 |
| 8. A small-grained siliceous conglomerate | 0 | 4 |
| 9. Oolitic limestone | 2 | 6 |
| 10. Rubbly oolite containing quartz pebbles | 4 | 0 |
| 11. Red marl | 1 | 6 |
| 12. Hard red sandstone | | |
| 13. Finely-grained sandstone | | |

| | ft. | in. |
|---|---|---|
| 14. Gritty sandstone | 1 | 6 |
| 15. Red sandy marl | 0 | 3 |
| 16. Rubbly limestone with quartz pebbles | 1 | 5 |
| 17. Grit | 1 | 6 |
| 18. Grit | 1 | 0 |
| 19. Grit | 1 | 0 |
| Red and blue marl | 1 | 6 |
| 20. Grit | 0 | 6 |
| Variegated marl | 3 | 0 |
| 21. Grit | 12 | 0 |

Middle Limestone.

| | ft. | in. |
|---|---|---|
| 22. Oolitic limestone, three beds | 11 | 0 |
| 23. Red marl | 0 | 6 |
| 24. 25. 26. } Limestone, occasionally nodular; partly oolitic and contains quartz pebbles | 22 | 0 |
| 27. Encrinal limestone with Caryophyllia | 8 | 0 |
| 28. Grit, varying in thickness from 2 inches to... | 1 | 6 |
| 29. Oolitic limestone | 7 | 0 |
| 30. Oolitic limestone | 1 | 0 |
| 31. Bluish clay | 0 | 6 |
| 32. Limestone | 4 | 6 |
| 33. Limestone | 2 | 0 |
| 34. Limestone | 6 | 0 |

Middle Grit.

| | ft. | in. |
|---|---|---|
| 35. Grit | 2 to 3 | 0 |
| 36. Gritty marl | 4 | 0 |
| 37. The strata here assume a basin shape, the cavity being filled with alternating beds of grit and marl | | |
| 38. Grit | 3 | 0 |
| 39. Limestone containing quartz pebbles | | |
| 40. Grit | 4 | 0 |

To the last succeed several alternations of marl and grit, but they are too much decomposed to permit their line of separation to be determined.

In Monmouthshire as at Bristol, the upper limestone shale consists of alternating beds of grit, shale, and limestone, showing a complete transition from the overlying millstone grit, into the great calcareous mass beneath. In a section of the strata subjacent to the coal measures of the Forest of Dean, Mr. Mushett describes beds of grit with subordinate red sandstone, marl, and limestone, similar to those of the coal tract near Oswestry, (see p. 145,) except that in Shropshire the red sandstone is much more prevalent than in Gloucestershire. To the north of Chepstow, these and other strata of thin-bedded impure limestone of dark dingy red and yellow colours, (upper limestone shale, &c.,) are wrapped in contortions *over* the great massive limestone of the Wye, and it is to these contortions, as drawn by Dr. MacCulloch, that Dr. Buckland and Mr. Conybeare have adverted.

On the other hand, the lower limestone shale rising from *beneath* the same limestone, appears in great force along the edges of the Old Red Sandstone of the high region between Chepstow and the Usk, and has been recently laid open by cutting the new road between these places. These beds very much resemble the upper limestone shale, and as that rock indicates a passage into the overlying millstone grit, so do the latter prove the transition into the underlying Old Red Sandstone.

Thus in travelling from Chepstow to Earlswood Common and Wentwood, we pass from older to older beds of limestone, till we reach those solid escarpments of the lower part of the formation as exhibited in the ravines between Well Head and Rug's Hole[1]. These rocks are underlaid by alter-

[1] These two places are so named as being the extremities of one of those "swallows" in which streams are lost, and which are so common in limestone tracts. The small brook which flows by White Mill is lost at Rug's Hole and re-appears at Well Head after a subterranean course of about a mile and a half. Near Well Head the carboniferous limestone is capped by a fine mass of dolomitic conglomerate. (See Map.)

nations of thin-bedded, reddish and purple shale, yellowish sandy limestone and sandstone, and finally by flaglike purple red sandstone, forming the upper part of the Old Red System. The alternating beds of impure limestone, &c., as developed between White Mill and Rug's Hole, are so unlike any other beds of the carboniferous limestone, that if they happened to be thrown up in arched forms, (as is the case in adjacent districts[1],) they might at first sight puzzle any observers, since they have much the character of the lower Silurian rocks, like which the sandstone beds are also frequently marked by the frequent impression of crinoidal stems. In this section, however, and again near Tintern Abbey and in parts of Pembrokeshire, the position of these beds is so clear, i. e. they so distinctly overlie every portion of the Old Red Sandstone, and further, contain the carboniferous fossils, that they are completely established as the true beds of transition between the carboniferous and Old Red Systems; the precise boundary line being drawn at that part where traces of the fossils and shale of the carboniferous system finally terminate, and the red sandstone fairly sets in[2].

Natural sections such as we have been considering, and which lay open the transition of one group of rocks into another, are only to be sought in these regions where the conterminous systems are much developed. This expansion of the carboniferous limestone is so considerable in the eastern division of Monmouthshire and adjacent parts of Gloucestershire, where the beds of passage are best seen, that the formation, which on the edges of the South Welsh coal-field rarely if ever exceeds five hundred feet, has here probably a maximum thickness of one thousand feet; for in the Forest of Dean, where the upper and lower shales are attenuated, as compared with the same beds between Chepstow and Usk, Mr. Mushett, an eminent practical miner, has determined the dimensions of the formation to exceed seven hundred feet. The passage from the lowest beds of the limestone into the system of Old Red Sandstone, is analogous to that which I have previously pointed out in the central counties of England, between the *uppermost* part of the carboniferous strata, and the lowest part of the new red sandstone, the phenomena in all these cases being displayed, in those districts where the respective portions of these systems are the most developed. (See chapter 4.)

I cannot terminate this account of the structure of the carboniferous limestone and associated rocks, without reverting to a phenomenon to which I directed attention in describing the Salopian coal-fields, and which is equally apparent throughout South Wales; viz. the *entire absence of coal, either in the millstone grit, or underlying limestone*; while in the North of England, on the contrary, the writings of Sedgwick, Phillips and others, have taught us, that these lower members of the carboniferous system, are there made up of almost indefinite alternations of sandstone, limestone, shale, *coal*, and ironstone. This neat separation of the carboniferous system of the central counties of

[1] At the Abbey one mile north of the Ship Inn near Alveston, and eleven miles north of Bristol, a small boss of these beds has been recently cut through in lowering the road. In the fine section of the Avon these beds also exist in full force. (See description and sections, in a subsequent chapter on Tortworth.)

[2] Professor Phillips, in his second volume of the Geology of Yorkshire (p. 15 et seq.), has described alternating red sandstone and limestone of this age, near Kirby Lonsdale.

England and of South Wales into an upper zone which is *productive* of coal, and a lower in which no traces of the mineral have been discovered, will in the sequel assist us in establishing important inferences, concerning the age of the *culm*-bearing rocks of Pembrokeshire and Devonshire.

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The undermentioned fossils have been found in the carboniferous limestone of Shropshire, Monmouthshire and South Wales:

| | *Chief Localities.* |
|---|---|
| *Productus hemisphæricus.* M.C. t. 238. | Coal Brook Dale and Oswestry. |
| —— *Martini.* M.C. t. 318. f. 2, 3 & 4. | Clee Hills, &c. |
| —— *comoïdes.* M.C. t. 239. | Salop and South Wales. |
| —— *costatus*[1]. Phill. pl. 7. f. 2. | Oswestry, &c. |
| —— *margaritaceus.* Phill. pl. 8. f. 8. | |
| —— *setosus.* Phill. pl. 8. f. 9. | |
| —— *punctatus.* Phill. pl. 8. f. 10. | |
| *Spirifer attenuatus.* Phill. pl. 9. f. 13. | Pembrokeshire. |
| —— *connivens.* Phill. pl. 11. f. 2. | |
| —— *imbricatus.* Phill. pl. 10. f. 20. | |
| —— *filiarius.* Phill. pl. 11. f. 3. | |

| | *Chief Localities.* |
|---|---|
| *Spirifer papilionaceus.* Phill. pl. 11. f. 6. | |
| —— *radialis.* Phill. pl. 11. f. 5. | Pembrokeshire. |
| —— *resupinatus.* Phill. pl. 11. f. 1. | |
| —— *semicircularis.* Phill. pl. 9. f. 15 & 16 | Littleton on Severn. |
| —— *bisulcatus.* M.C. t. 494. f. 1 & 2. | |
| —— *cuspidatus.* M.C. t. 120. | Clee Hills, Shropshire. |
| —— *distans.* M.C. t. 494. f. 3. | |
| —— *octoplicatus.* M.C. t. 562. f. 2, 3 & 4. | |
| *Terebratula fungites.* MSS. Phill. | |
| —— *ambigua.* Phill. pl. 11. f. 21. | Pembrokeshire. |
| —— *radialis.* Phill. pl. 12. f. 40 & 41. | |

*Crinoidea* occur in vast profusion, including genera and species described by Miller from the limestone of Bristol. *Corals* also are in parts very abundant (see chap. 7). *Orthocerata* are very rare, and I never found one with well-marked characters. *Trilobites* are also scarce, but a few examples of them have been detected by the Earl of Cawdor in the coast cliffs near Stackpole, Pembrokeshire, among which are caudal portions of *Asaphus seminiferus* and *A. granuliferus* of Phillips. The *Ichthyodorulites* of this formation are of peculiar forms and have been described by M. Agassiz; among them is the *Ctenacanthus tenuistriatus* of the Clee Hill limestone, (p. 119.). Other species occur near Bristol.

Considering this formation to be well known, I did not collect many organic remains, so that after all the list is very incomplete. We may, however, consider it as a sample of specimens taken from various localities; and viewing them in this light it is worthy of remark, that every species above enumerated has been previously described by Professor Phillips as occurring in the limestone of this age in other and distant tracts. On the southern edge of the South Welsh coal-field, particularly between the Mumbles and Pennard, west of Swansea, the carboniferous limestone has been diligently explored by my friend Mr. Dillwyn, M.P., whose skill in conchology has enabled him to detect many species in addition to those commonly observed in the formation. In his list, which has not yet been published, he enumerates—

*Ammonites*? and *Goniatites*, 2; *Bellerophon*, several species; *Cirrus*? several; *Dentalium*, 1; *Euomphalus* several; *Eulima*? 1; *Littorina*, 3; *Lutraria*, 1; *Melania*, 3; *Natica*, 1; *Orthocerata*, several; *Turbo*, 1; *Trochus*, 3; *Turritella*, 4; *Rotella*, 1, &c. Among these also Professor Phillips has also recognised many published in his work, while Mr. J. de C. Sowerby coincides with me in opinion *that not one of these species has yet been found in the Old Red or Silurian Systems.*

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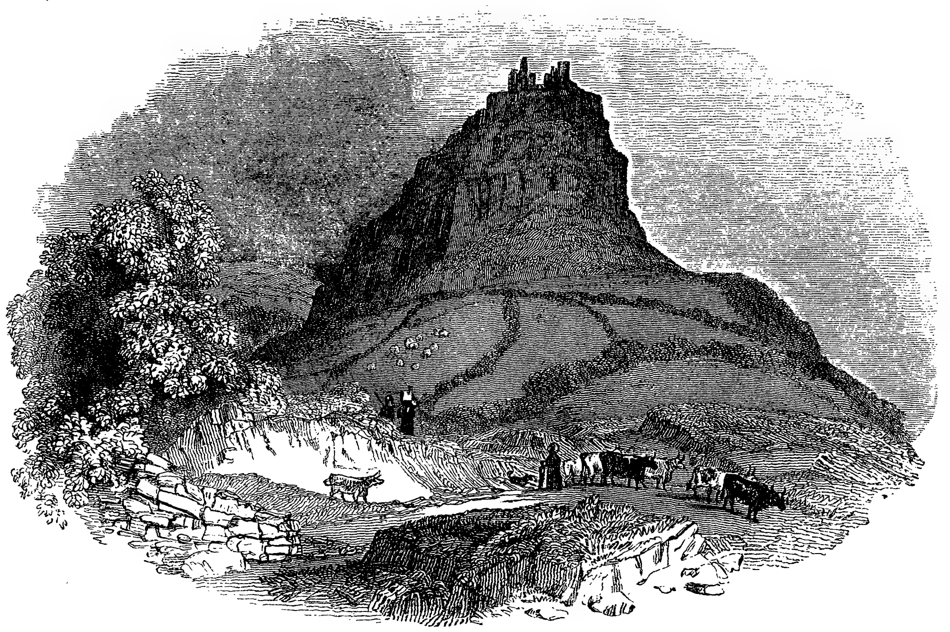
[1] For the sake of uniformity and to prevent the possibility of error, the names *Spirifer* and *Productus* are used throughout. Mr. Phillips writes *Spirifera* and *Producta.*

18.



*Castle Cerrig Cennen. (From a drawing by Mrs. Stackhouse Acton.)*

# CHAPTER XIII.

## CARBONIFEROUS SYSTEM (*concluded*).

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### *Principal Outliers and Dislocations of the Carboniferous Limestone on the northern and western edges of the South Welsh Coal Basin.*

1. *Pen Cerrig-calch.* (Pl. 31. fig. 1.)—THE chief masses of the carboniferous limestone being described, it now only remains to give a sketch of the prominent dislocations and outliers of the formation in South Wales.

The strata of Old Red Sandstone, carboniferous limestone, and millstone grit, composing the margin of the South Welsh coal-field, are all clearly exposed to the south of Crickhowell, where the river Usk flows in a deep and broad valley between these rocks and the loftier mountains of Old Red Sandstone constituting the Black Forest. Observing in the Ordnance map that the summit of one of these mountains was marked

"Pen Cerrig Calch" (*Angl.* the limestone Crag), I ascended to ascertain why such a name had been used in a district appearing to consist exclusively of the Old Red Sandstone. (Pl. 31. fig. 1.) I also perceived that the lower sides of these hills were precisely similar in structure to those of the Old Red Sandstone in the opposite escarpment of the coal-field. The quartzose conglomerate or top of the Old Red Sandstone (which will be described in the next chapter) stands out in the great "ecroulement" of rocks named Daren, and also in the Beacon Hill, both acting as "contreforts" or supports to the higher mountain summit; and lastly I found in the culminating point of the arid and lofty mountain of Pen Cerrig Calch, 2200 feet above the sea, that the limestone, not less than fifty feet thick, occupied an isolated yet distinct escarpment covered by the true millstone grit, the latter having a thickness of about one hundred and fifty or two hundred feet, and thus all the relations were completely established. In this outlier, therefore, we find a much smaller development of the limestone than in the main escarpment of the coal-field, where the formation occasionally swells to a thickness of several hundred feet. The chief mass is thick-bedded, compact, and subcrystalline, of a cream colour and without fossils; but in some of the thinner beds on the southern face of the mountain, where they disappear beneath the cap of millstone grit, they become oolitic and contain a few organic remains,—Productus, Terebratula, Corals, and Encrinites, but all those which I collected were in too imperfect a condition to be capable of specific description[1].

The grooved and sinuous surfaces upon the weathered bosses of this rock will remind the traveller of those limestones, which have been long exposed to the atmosphere in very lofty situations; for they strongly recalled to my memory similar appearances in the calcareous peaks of the Eastern Alps. The beds of Pen Cerrig Calch are inclined at the very gentle dip of six or seven degrees to the south-east, and if the planes of stratification be prolonged towards the Blorenge mountain near Abergavenny, to which they point, we find that this limestone would be carried much below its natural position in the escarpment of the coal-field; in other words, the limestone would be brought far beneath the surface of the Old Red Sandstone, the rock which in undisturbed positions forms its natural support. Again, the inclination of these hills is to the south-east, whilst the same beds in that portion of the escarpment of the coal-field which is nearest to Pen Cerrig Calch, dip to the south. (See Map.) We have thus clear proofs of violent dislocations, along the external margin of the coal-field, by which certain members of the Old Red Sandstone have been so thrown up as to circle round the basin, whilst the chief masses of the system from which they have been detached, still occupy the broad mountainous range of the Black Forest, and of which Pen Cerrig Calch forms a part. This fact is a strong additional testimony, that although the adjoining carboniferous deposits may have been accumulated in a depression, yet their present basin shape has been produced by great dislocations. The removal of

[1] This limestone was formerly burnt for lime, but is now abandoned on account of the expense, caused by the distance from coal, the height of the mountain, and the want of roads.

the enormous masses of millstone grit and carboniferous limestone which formerly connected "Pen Cerrig Calch" with the South Welsh coal-field, and the formation of the present valley of the Usk, which is here five miles broad and nearly 2000 feet deep, may both be ascribed to violent dislocations and the subsequent action of powerful currents of water; this valley is, therefore, unquestionably "a valley of denudation." (See Pl. 31. fig. 1.)

The term denudation, however, has been made use of to express so many operations of water, differing from each other in intensity and in their nature,—some geologists meaning to express thereby, sudden ravages occasioned by a transient but powerful flood, others seeing in it nothing more than the gradual work of rivers, formerly in a more violent state of action,—that it is well to explain what may have been the operations employed in producing the phenomena in question. The longitudinal depression in which the Usk now flows, is simply a great line of fault, determined no doubt by one of those movements of elevation which have broken up the escarpment of the coal basin and thrown it into its present form. Earthquakes and subterranean forces, sufficient to upheave the stupendous mountain masses of conglomerate and sandstone of the Fans and of the Black Forest, and to snap off huge portions of the chain, as well as raise them into the circular escarpments of the coal-field, could not have acted on such large accumulations of solid sedimentary matter, without occasioning immense transverse openings or gullies. On the supposition that these oscillations were going on for a long time *before* the deposits were raised *above the surface of the waters,* how powerful must have been the submarine currents set in action by these changes of level! How must they have affected the bottom of the sea! How deeply must such currents have channelled out the hollows into which they were deflected! By all these combining causes it is conceived, that the valley in question was both determined and subsequently deepened and increased.

Whatever hypothesis may be advanced to account for the present position of the lofty outlier of Pen Cerrig Calch, the detritus of those materials, which formerly united it with the South Welsh coal basin, is still piled up in vast mounds and terraces of gravel on both banks of the Usk to attest the work of destruction, the effects of which will be further noticed in the two concluding chapters of this work.

### 2. *Other dislocations and outliers of the Carboniferous Limestone.*

Passing unnoticed all minor derangements, I shall here describe great dislocations only, which have affected the carboniferous limestone and upper portions of the Old Red System, and have tended to give the South Welsh coal-field its present configuration.

The tract in which they occur is included between the Caermarthenshire Fan on the

east and the parallel of Llandeilo Fawr on the west, a distance of about twelve miles. On referring to the map it will be seen, that while the lower members of the Old Red Sandstone are nearly vertical, and preserve the same rectilinear strike (north-east to south-west) as the parallel ridges of Silurian rocks which trend from Shropshire to Caermarthenshire; the upper members of the same system, which are slightly inclined, constitute lofty mountains, and have, on the whole, a curvilinear direction, conforming to the margin of the coal basin.

The dislocations I shall describe, are two which occur near the Caermarthen Fans, and one at Castell Cerrig Cennen.

The western end of that portion of the escarpment of the South Welsh coal-field, which is occupied by the Caermarthen Fans, exhibits a very powerful transverse fault, by which the upper strata of the Old Red Sandstone have been so thrown up, as to occupy the summit of Fan-sirgaer, 2200 feet above the sea; while in the contiguous mountain of Carreg-ogof, the same beds, covered by carboniferous limestone and millstone grit, lie at the height of not more than 1500 feet; and hence the Old Red Sandstone of the Fans is proved to have been upcast to an extent of at least 700 feet[1]. The direction of this transverse fault is nearly from north to south, as marked by the fissure in which the rivulet Twrch-fechan flows, in its descent from the edge of the escarpment towards the centre of the coal basin. On the left bank of this rivulet all is Old Red Sandstone, while a little to the right is the millstone grit of Carreg-las, the limestone being entirely lost for the space of nearly two miles. The elevated mass of Old Red Sandstone dips ten to twelve degrees S.S.E. the limestone and millstone grit being inclined twenty degrees to the south. This inclination of the limestone accounts for its rapid disappearance beneath the millstone grit of Carreg-las, and connected with the great upcast of the fans, explains how the latter rock has been thrown into juxtaposition with the Old Red Sandstone.

Immediately to the west of the great limeworks of Cloganmawr, there is another considerable fault. (Pl. 30. fig. 12.) After occupying the terrace-formed ridge, on which the kilns are situated, the limestone is abruptly snapped off, and thrown down about 200 feet beneath its usual level into a morass, the ends of the lower strata only being visible on the side of the mountain rill. This is the spot above Blaen-Cennen, where the limestone presents the peculiar glazed surface before described. (See p. 156.) The strike of this dislocated mass is 10° to the north of west, and the inclination, differing from that of the adjoining lime quarries, is 25° south by west. This downcast, though not exhibiting so great an amount of disturbance as that of the upcast of the Old Red Sandstone in Fan-sirgaer, exhibits in one respect analogous phænomena. In both cases large portions of the lip of the coal-field present the appearance of having been

[1] The adjoining portion of the edge of the basin to the east of this tract has been examined by Mr. Conybeare and Mr. Maclauchlan, who have favoured me by colouring the quarter sheet of the Ordnance map in which Merthyr Tidvil is situated.

extruded from their regular line of bearing, and forced into the area of the Old Red Sandstone by movements which miners would call "lateral shifts"; an explanation which would naturally suggest itself by inspection of the relative position of the masses on the map. These appearances can, however, be more simply explained by the upward and downward movement of the faults in question, and by the different angles at which the separate masses are inclined[1].

The limestone emerging from this morass at Pant-y-gwasted, where the strike is true south-westerly, is well exhibited in low parallel ridges crowned by high ridges of millstone grit. The strata dip S.E. and S.S.E. at angles of about 30°. These calcareous terraces diminish successively in height, and terminate near the cavern from which the river Lwchwr bursts forth. Between this point and the house of Cwrt-a-barddh the limestone is wanting, and the distance is occupied by the Old Red Sandstone or its detritus.

The surface of the ground near the source of the Lwchwr is singularly marked by several funnel-shaped cavities, which are not peculiar to the limestone of this spot, but are also observable along the lines of greatest dislocation around the promontory of Carreg-ogof, and beneath the northern face of Carreg-las. They seldom exceed 60 to 70 feet in their diameter at the surface, tapering downwards to depths of 30 to 40 feet, and apparently terminating in vertical tubes. As they occur at or near points of the greatest dislocations of the strata, may we not be allowed to speculate upon their having formerly been the spiracles by which certain gases were evolved, during those periods when earthquakes produced the adjoining elevations and depressions of the strata?

I invite special attention to the locality of Cwrt-a-barddh, because this portion of the margin of the coal basin is directly opposite to the remarkable outlier of carboniferous limestone called Castell Cerrig Cennen, with the position of which I shall now attempt to prove that the break in the escarpment is directly connected. (See Map.)

### 3. *Castell Cerrig Cennen.* (Pl. 34. fig. 6.)

The picturesque ruin called "Castell Cerrig Cennen," is built upon an insulated rock of carboniferous limestone, which projects in bold relief on the right bank of the little stream called the Cennen, and nearly in the centre of a valley in the Old Red Sandstone, as represented in the wood-cut at the head of this Chapter[2]. (See also Pl. 34.

[1] This solution of the *modus operandi* was first, I believe, suggested by Mr. Lonsdale, from the examination of a series of beautiful models. He is in possession of much valuable knowledge respecting mineral faults and their complications, which I trust he will soon lay before the public.

[2] I am indebted to Mrs. Stackhouse Acton for a beautiful sketch of Castell Cerrig Cennen, from which the wood-cut is engraved. The castle is the property of the Earl of Cawdor, and being one of the most striking ruins in South Wales, is well worthy of the attention of the antiquary. The well of the fortress (supposed to have been reached by cutting to a great depth through the solid rock) is, I believe, a natural fissure.

fig. 6.) The breadth of this valley between the escarpment of the carboniferous limestone on the south, and the Silurian rocks on the north, does not exceed two miles. It will hereafter be shown, that the full development of the Old Red Sandstone terminates at Pont-ar-lleche, and as that system is not laid open by any transverse gorge in the valley of the Cennen, no accurate opinion can be offered respecting all the strata of which its chief and central masses may be composed. The uppermost beds, however, present a thin zone of conglomerate and grit, and the lowest tilestones are distinctly exhibited between Cerrig Cennen and the vale of the Towy. The intermediate strata, upon some of which the limestone outlier of Cerrig Cennen is placed, are argillaceous and sandy; those on the north side of the castle being vertical and unconformable to the bedding of the calcareous rock, while those at its southern base, though imperfectly exhibited, are apparently twisted under the limestone.

The calcareous beds of "Cerrig Cennen" are well exhibited, and consist of the black and grey varieties of the adjacent carboniferous limestone, inclosing the same fossils; viz., *Productus hemisphæricus*, *P. Martini*, and large bunches of one of the corals peculiar to this formation, (*Lithodendron sexdecimale*, Phill., &c.)

The precipitous face or escarpment of the rock on which the castle stands, is exposed to the depth of about 60 feet, the summit of the hill being between 250 and 300 feet above the Cennen. The remainder of the declivity from the base of the rock to the river, is covered by a steep grassy slope, which conceals almost entirely the strata below the limestone; but at one point the Cennen has worn away a small portion of the talus, and exposed a few feet of red sandstone, which appear to dip, as before said, unconformably under the limestone of the castle hill.

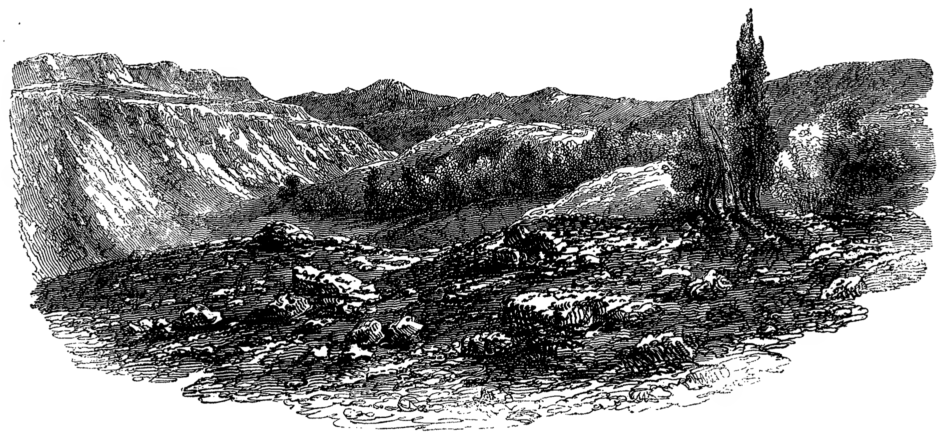
On the left bank of the Cennen the strata of Old Red Sandstone interposed between the outlier and the main escarpment of the carboniferous limestone, are so concealed by detritus, that traces of them are to be detected only in the bed of one small rivulet. On ascending, however, to the site of the great fault already described, or towards the break in the zone of limestone above alluded to, we find the upper member of the Old Red Sandstone plunging to the south beneath the limestone on one side of the ravine, at an angle of seventy degrees, and on the other of thirty or forty degrees to the south-east (sources of the Lwchwr). Seeing that the sudden break in the continuity of the main escarpment of the limestone is exactly opposite the outlier Cerrig Cennen, and that this dislocated mass would, as nearly as could be estimated, fill the portion of the gap which is between the spring head of the Lwchwr and the house of Cwrt-a-barddh, it might at first be concluded, that the rock Cerrig Cennen had been torn from its parent seat, and precipitated down the shelving escarpment upon the surface of the Old Red Sandstone; an inference which would not appear extravagant in this region of violent disturbance. But though highly curious and different from that of Carreg-las already described, or of any other detached mass along the frontier of the South Welsh coal-field, the dislocation of Cerrig Cennen may be simply explained. It is evident from

the abrupt escarpment of the chief mass, that the carboniferous limestone must once have extended over a considerable portion of the valley, and probably far to the westward of the castle. It is also evident from the opposite inclination of the strata on each side of the gap at Cwrt-a-barddh and from the beds on which the castle stands dipping away from the main escarpment, that the whole of the district has been violently broken up. We have therefore data for inferring, that the part of the valley situated between the outlier and the boundary of the coal-field was once the scene of a great disturbance, and that a body of water similar to that we have supposed to be in existence in the case of Pen Cerrig Calch (p. 162.) has subsequently removed the intervening masses of strata, leaving the Cerrig Cennen a monument of its devastating action.

It is not my intention to describe the other dislocations in the carboniferous limestone on the south-western edge of the South Welsh coal basin, as they will form a portion of Mr. Conybeare's memoir. It is sufficient to say that they all exhibit, though sometimes in a minor degree, nearly the same phenomena as have been here delineated. Some of the general inferences which may be deduced from these facts will be noticed in a subsequent chapter, after the reader has been made acquainted with the disruptions of the older rocks.

Repeating, however, an observation deduced from similar phenomena in the Clee Hills, I will here merely observe, that the method by which the strata surrounding and supporting this coal-field have been fashioned into the broken margin of a basin, is clearly indicated by numerous and powerful transverse dislocations[1].

[1] See p. 119.



# CHAPTER XIV.

## OLD RED SYSTEM.

1. *Conglomerate and Sandstone.*—2. *Cornstone and Marl.*—3. *Tilestone.*

THE rocks known to English geologists under the name of the Old Red Sandstone, consist of various strata of conglomerate, sandstone, marl, limestone, and tilestone, the youngest beds of which dip conformably beneath the carboniferous deposits, whilst the oldest repose upon and pass into certain grey-coloured rocks. These grey-coloured rocks form the upper part of the Silurian System. (See coloured section upon the Map, also Pl. 31. figs. 1 to 4, and wood-cut p. 171.)

Being convinced that the Old Red Sandstone is of greater magnitude than any of the overlying groups, I venture for the first time in the annals of British geology to apply to it the term *system*, in order to convey a just conception of its importance in the natural succession of rocks, and also to show, that as the carboniferous system, in which previous writers have merged it[1], (but from which it is completely distinguishable,

[1] See even the very recent vocabulary used in the Bridgewater Treatise by Dr. Buckland, in which the Old Red Sandstone is made a subordinate part of the carboniferous system, the same divisions being there retained which were first put forth by Mr. Conybeare. Mr. Lyell, however, has in great measure adopted the classification here proposed. Professor Sedgwick, and myself, have examined these rocks over a wider area, perhaps, than most English geologists, and he coincides in the necessity of separating the Old Red Sandstone from the overlying and subjacent systems. (See memoir by Professor Sedgwick and myself on the Old Red Sandstone of the Highlands of Scotland. Geol. Trans. vol. iii. and subsequent memoirs by Professor Sedgwick, Geol. Trans. vol. iv.) The Norwegian rocks should be examined in detail by some competent observer to decide how far

both by lithological characters and zoological contents,) is surmounted by one red group; so is it underlaid by another, this lower red group being infinitely thicker than the upper. The chief reason, perhaps, why the Old Red Sandstone has not been considered as entitled to the rank of a system is, that in France and Germany its equivalents are ill, if at all, developed. It has, however, been recognised in Poland and Silesia, while in Norway there are mountain ranges very similar in structure to the types of this system in the North of England, Scotland, and Ireland. As, however, there is no region of Europe yet examined, where the Old Red Sandstone is better exhibited than in the British Isles, so there is no part of the kingdom in which it is so much expanded as in the country here described. Occupying the largest portion of Herefordshire and the adjacent districts of Worcestershire and Shropshire, it spreads over wide tracts of Monmouthshire, surrounding the coal-field of the Forest of Dean; and forming a girdle round the great South Welsh coal basin, it constitutes in Brecknockshire the loftiest mountains of South Britain. The *enormous* thickness of the red stratified deposits, included between the coal measures and the Silurian rocks, will at once be comprehended by any observer who places himself on the eastern slopes of the latter on the Welsh borders of Herefordshire (near Kington, for example); whence casting his eye to the south and south-east, the circle of vision, although extending over all the mountains between the Wye and the Usk, and terminating only in the lofty mountains, called the Brecon and Caermarthen fans[1], 2500 feet above the sea, embraces nothing but Old Red Sandstone! (See vignette, head of the chapter.) This view does not include a wide superficies, occupied merely by undulating masses of the same strata, but a territory in which *successive* members of the system rise from beneath each other in distinct mountainous escarpments. The same succession, though in a much smaller scale, is displayed in Shropshire, between the coal-field of the Clee Hills and the older rocks of Ludlow; whilst in the central districts of Herefordshire the strata lie in a great basin, the lower edges of which are turned up against the Silurian rocks, both on their eastern and western flanks.

For the convenience of description, a triple subdivision of this system is adopted; the strata being described in descending order under the following names[2]:

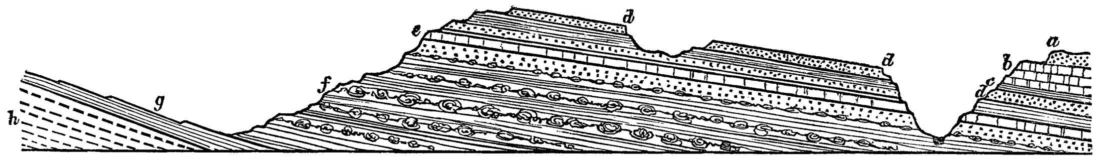
1. *Quartzose Conglomerate and Sandstone.*
2. *Cornstone and Marl.*
3. *Tilestone.*

they agree in order and in characters with the older strata of the British series; but as I shall hereafter show, that the Silurian System is there largely—perhaps fully developed, so we have every reason to suppose that the mountain masses of the red conglomerate and sandstone of that kingdom represent our Old Red System. Pusch, indeed, has shown the existence of Old Red Sandstone in Poland, and it is supposed to rise from beneath the coal-fields of Bohemia and Silesia. To what extent does it exist in Russia?

[1] "Fan:" *Anglicè*, a covering or cap, i. e. the summit.

[2] A similar subdivision of the Old Red Sandstone was first proposed by Buckland and Conybeare in their memoir on the Bristol district.

20.




*a.* Millstone Grit. *b.* and *c.* Carboniferous Limestone and Shale (overlying rocks described in the preceding chapters.)

The Old Red System consists of *d, e, f,* and *g*: viz. *d* and *e. Conglomerate and Sandstone; f. Cornstones and Marl; g. Tilestone.*

The Ludlow Rocks (upper formation of the Silurian System) appear rising from beneath the Old Red System at *h.*

In the descriptions which follow it will, however, be seen that the distinctions implied by these names are not absolutely peculiar to any one of the three divisions, but are under certain limitations repeated in each. Thus, though tiles are largely quarried in the lowest strata throughout extensive tracts of country, beds almost equally fissile occur partially both in the bottom part of the uppermost, and in the central or cornstone division: while, on the contrary, at Tortworth and Thornbury in Gloucestershire, and in parts of Monmouthshire, conglomerates are met with below the upper zone; and in Pembrokeshire they even take the place of tilestones in the lowest strata. (See Pl. 36. fig. 17. and Pl. 35. fig. 6.)

Let us commence the description of these deposits at the north-western edge of the coal basin of South Wales, where the upper zone or formation is very largely and clearly developed.

*Quartzose Conglomerate and Sandstone.* (See Pl. 31. fig. 1. and *d, e* of wood-cut.)

The loftiest points occupied by the Old Red Sandstone of England are the fans of Caermarthen and Brecon, the former 2590 and the latter 2500 feet above the level of the sea. The southern face of these mountains, like most other parts of the edge of the South Welsh coal basin, slopes in a gentle talus, inclined from ten to twelve degrees towards the centre of the coal-field, and is usually covered by turf or bogs. When these coverings are removed, a conglomerate, composed of pebbles of white quartz in a red matrix, forms the upper member of the Old Red Sandstone, or substratum of the carboniferous limestone. To the south of Abergavenny, and all along the northern edge of the coal-field, the conglomerate occupies this relative position, dipping beneath the limestone and cropping out near the summit of the steep escarpments. In the Blorenge mountain near Abergavenny, the upper beds immediately underlying the limestone, are quartzose grits, with a slightly calcareous cement, containing occasionally pink and white pebbles of quartz, varying from the size of a mustard-seed to that of two and three inches, sometimes mixed up with grains of a green colour and compact felspar. Other and lower beds, however, are pure quartzose conglomerates. When fresh quarried, the conglomerate is sometimes of a pink or reddish colour, but after

long exposure it frequently becomes nearly white, in which state it might be mistaken for the coarser beds of the millstone grit, but it is separated from them by the carboniferous limestone. The conglomerate beds occupy a thickness of about two hundred feet, and pass down into chocolate brown, and reddish, coarse-grained sandstone, with blotches of red shale and occasionally a very small pebble of quartz. Near the Caermarthen fans the conglomerate beds are from three to four feet thick, and inclose fragments of felspar, hard schist, and black slate. Similar beds, with the same relations, form a continuous girdle round the coal basin of the Forest of Dean, and the tourist upon the Wye may observe excellent examples of them in the promontory which advances to the west of the picturesque cliffs of Symonds Yat, between Monmouth and Ross. Again, these conglomerates are seen in great masses on the right bank of the Wye, to the north of Tintern Abbey, from whence they range southwards over a considerable district of Monmouthshire, extending along the summit of Wentwood, the highest ground between Chepstow and Usk. (See Map.)

In the beds immediately below the conglomerate, the pebbles gradually disappear, until the rock becomes a pure sandstone of brownish and occasionally of delicate gosling green and deep red colours: other beds are much spotted with green blotches on a dark red ground. All the escarpments of the lofty mountains of the Brecon and Caermarthenshire fans, and extending thence into the neighbourhood of Abergavenny, exhibit a like succession of underlying strata of brownish red and greenish grey sandstones, fine-grained, hard, and sometimes thick-bedded, the mica being, for the most part, intimately mixed with the other components of the stone. These sandstones alternate with bands of red and green argillaceous marl. Where roads are contiguous, the sandstone is quarried for troughs, cider-presses, and all building purposes. Some of the lower layers of this division are so thin-bedded as to split into tiles, a character, however, which is not common. Other courses of the sandstone have a strong flaglike tendency, and the fine-grained purplish brown sandstones of the Fan bwlch-y-chwyth, near Tre-castle, are quarried for flagstones, which are transported as far as Llandovery. Other varieties are sufficiently fine-grained to be used as whetstones. These rocks are separable from the underlying groups, not only by their position, but also by containing no beds sufficiently calcareous to be burnt for lime. It must, however, be observed, that in many situations where this subgroup is much expanded, particularly on the northern sides of the Blorenge, the fans of Brecon, and other portions of the margin of the South Welsh coal-field, it contains occasionally thin courses, two or three in a mountain side, of mottled, red and green, very impure limestone, which is undistinguishable from some of the least calcareous beds of cornstone in the central part of the system. The bold scar[1] called the Daren, two miles north of Crickhowell, offers a fine vertical section of a portion of this division. We there see a greenish, fine-grained, thick-bedded sandstone (an excellent building-stone), alternating with purple, red, and green, finely laminated, marls, and other thin courses of hard sandstone and fine conglomerate. In the latter I detected the scale of a large fish which has not yet been described by M. Agassiz. Similar beds of red and green impure cornstones, are observable midway in the escarpment of the Blorenge,

[1] The Daren owes its form to a great subsidence of the rock, the fragments occupying a rough talus above the valley of the Usk. I much regret that my own imperfect sketch of this picturesque scene is not worthy of being engraved.

as laid open upon the sides of the inclined plane by which the limestone is conveyed to the Abergavenny Canal. The sides of this inclined plane expose one of the best sections I am acquainted with, extending upwards from the cornstone which appears in the valley, to the conglomerate, the great mass of which lying above the top of the inclined plane, is covered by the mountain limestone and millstone grit. The upper masses of the mountains between the Usk and the Wye, occupying various lofty eminences from 1800 to 2545 feet above the sea, and known under the general name of the Black Mountain, together with the Skirrid, are composed of brownish red and greenish sandstones, passing downwards into the concretionary and fragmentary rocks of the next division. The Skirrid is partially capped by quartzose conglomerate, and then exhibits in descending order—

1. Chocolate red-, and green-coloured thin-bedded hard sandstones.
2. Do., very finely grained, thick-bedded.
3. Mottled marls, red and green.
4. Thick beds of brownish or chocolate red, surfaces marked by irregular blotches or concretions of green and red marl of various forms. (See p. 179.)
5. Marls like No. 3.
6. Thick-bedded brown sandstone, becoming slightly calcareous and passing down into cornstone.

The greenish variety of sandstone in this section is composed of grains of sand and quartz, with spangles of mica, in a matrix of decomposed felspar, the colouring matter being probably chlorite, which together with the felspar of the matrix gives a trappean aspect to the rock when viewed in hand specimens. Again, some of the hardest sandstones, particularly where they pass into the blotchy marls and cornstones, are themselves slightly calcareous. Such characters may be observed in many other sections; but the greenish felspathic rock is a variety never seen in the system of New Red Sandstone. It again occurs in a remarkably compact state in the Old Red Sandstone of Caermarthenshire under Nelson's monument, on the left bank of the river Towey.

In the Black Forest, the masses dip slightly towards the South Welsh coal-field, the upper strata occupying the summits of long tabular ridges, which rise towards the north-west and present bold escarpments to the valley of the Wye. In some of these ridges, where the lower beds of the zone pass into the inferior cornstone and marl, tiles are largely worked, and other beds contain thin layers filled with fragments of carbonized vegetable matter; but I have never yet detected any remains sufficiently perfect to be compared with known fossil plants. These imperfect fragments of vegetables being accompanied by thin films of carbonaceous matter, have induced ill-advised speculators to drive galleries into the mountain sides in search of coal. It is scarcely necessary to add, that all these enterprises have failed. Remains of some of the works near the summit of the cornstone group are visible on the eastern side of a steep ravine above the village of Cusop, two miles south of the town of Hay.

No rock described in this work puts on a more ancient aspect than these sandstones as seen upon the north side of the Sugar Loaf, and in the wild gorges by which the great mass of the Black Forest is fissured. We must not, however, judge of the antiquity of rocks by their mineral aspect, nor even by their lithological structure; for, as I shall have occasion to show, there are many portions of the Old Red Sandstone (particularly in Pembrokeshire,) undistinguishable in these respects from the oldest greywacke

rocks, whilst strata of the *underlying* Silurian system, formerly termed greywacke, so far from assuming an air of higher antiquity, in numberless cases and over very large areas, resemble closely some of the younger secondary deposits.

The lower portion of this upper sandstone, caps the escarpment of the cornstone and marls both in the splendid mountain range of the Black Forest, and in the central parts of Herefordshire, appearing as thickly bedded sandstones of excellent quality for building, and is quarried for tiles in the hills south of Hay, as well as to the south-east of Weobly. In most other parts of Herefordshire, the upper sandstones thin out, the underlying cornstones rising to the surface; but in the north-eastern parts of the county, particularly round Bromyard, there are also sandstones which come within this division of the system. The finest examples occur in the large quarries of Bromyard Downs, on the road to Worcester, where there are light-coloured, slightly micaceous, finely grained, whitish or greenish sandstones, in beds of 6 and more feet thick, separated from each other by courses of deep red marly clay, and divided by vertical fissures partially filled with it. These quarries produce blocks of stone 20 feet long by 6 feet wide, and troughs of great depth. The cap of the rock consists of flaggy incoherent beds of a dingy red colour, with spots or blotches of greenish argillaceous marl. Whitish sandstones resembling those of Bromyard Downs, and of excellent quality, are quarried near Cleobury Mortimer, and others of red colour are extracted in large masses for cider-presses, in the range of the hills north of the Teme near Pensax. These strata alternate with marls and other sandstones, which are hard, flaglike, and micaceous.

In that district of Shropshire which environs the coal-field of the Forest of Wyre, and extends to the neighbourhood of Bridgenorth and Wenlock, the upper member of the Old Red Sandstone is generally ill exhibited, the only clear and unequivocal section of it being that which is exposed at Prescot Bridge and Oreton. (See Pl. 30. fig. 1.) Without the plainest evidence of superposition, this soft yellow sandstone might be mistaken for a coal-measure stratum, but as it is really overlaid by a quartzose conglomerate, which dips conformably beneath a band of true carboniferous limestone, and on the other hand reposes on cornstone, all doubts are dispelled, and like rocks of similar composition and colour which we shall hereafter notice in Pembrokeshire, the yellow sandstone of Prescot Bridge, is thus proved to belong to the upper division of the Old Red System.

Similar geological relations are displayed on the steep acclivities of the Clee Hills. The southern extremity of the Clee-barf (the Brown Clee,) is strongly marked by the exposure of the upper conglomerates and grits, though in some parts they are so grey as to resemble the overlying millstone grit. The upper beds of the Old Red here conform to the lowest sandstone of the coal measures, both being inclined at small angles, and affected by the same faults and dislocations. (See Chapter VIII. pp. 123 and 124, and Pl. 30. fig. 6.; and Pl. 31. figs. 3 and 4.)

These beds are less clearly exhibited on the slopes of the Titterstone Clee, except in the western face of the Knowlbury field, to the south of which, being much attenuated, and also thrown up at very high angles, they occupy only a small surface. In all these cases, the strata of this group dip under and support (conformably) the carboniferous strata, as in the escarpments of the coal basins of South Wales and the Forest of Dean.

There are many other situations, particularly in the proximity of coal-fields, (see Map,) where this subdivision exists; but I have only alluded to some of the best-defined instances. With the exception of a large fish scale detected near Crickhowell, no animal organic remains have yet been observed in this upper division; and although a few fragments of carbonized vegetables have been collected, none of these, as before said, are identifiable with the plants of the coal measures. In their imperfect state of preservation, the botanist can only decide that they belong to land plants. I have, however, little doubt that future observers will detect vegetable forms sufficiently well defined to be described; and I would recommend those ravines near Cusop to be well examined in which deep sections are exposed, as well as other parts of the escarpment of the Black Forest[1].

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## *Central or Cornstone Formation.* (*f.* of wood-cut and Pl. 31. fig. 1.)

The central masses of this system are chiefly composed of alternations of red and green argillaceous spotted marls, affording, on decomposition, the soil of the richest tracts of Brecknockshire, Monmouthshire, and Herefordshire; a large position of Salop, and small parts of Gloucestershire and Worcestershire. These argillaceous beds sometimes alternate with sandstone, but more frequently with irregular courses of concretionary impure limestone, mottled also red and green. When compact, the calcareous beds are termed simply limestones by the quarrymen, but when mixed with sand and marl, giving them a brecciated or conglomerate aspect, they constitute the well-known cornstone of these counties. The dull-green colour on the Map indicates the chief lines where these concretionary courses have been observed, though it is not pretended that all the points where calcareous rocks appear at the surface, are laid down; for the cornstone formation of the Old Red System contains so many inosculating and slightly persistent bands of concretionary limestone, in some cases mixed with marl, shale, and sand, in others assuming a subcrystalline form, that it is seldom practicable to separate the calcareous matter, even in any one district, into a given number of bands.

We may commence the detailed description of this formation in Caermarthenshire, because, although the cornstones in that county are of very impure quality, their relations are clearly exposed in a section exhibited in descending from the Caermarthenshire fans towards the bridge called Pont-ar-lleche. (See Pl. 34. fig. 5.) The river Sowdde here runs in a narrow cleft or channel which cuts the strata at right angles to their strike. The inclination of the beds is towards the south-east, and the dip varies from 65° near the superior limits of the formation, to 75° towards its base, or junction with the tilestones. In the short distance, therefore, of about three quarters of a mile, we obtain by means

[1] The shells and fishes of the Old Red System are described in subsequent chapters, followed by descriptions of the Silurian fossils.

of the high inclination of the strata, and the clearness of the section, a perfect knowledge of all the beds comprising the cornstone division, which, owing to their slight inclination and gentle undulations, are expanded over the low and fertile tracts of Brecknockshire and Herefordshire, and are there rarely well exhibited *as a whole*. The strata consist of deep red shale, argillaceous sandstone, and hard, quartzose, dingy purple, or brown sandstone, slightly micaceous; with intercalated calcareous beds, of a concretionary and pseudo-concretionary structure. These calcareous concretions, varying in colour from red to green, and in diameter from half an inch to three or four inches, are disseminated through the mottled marl, which becomes occasionally an impure limestone. They are arranged in bands occupying vertically from 8 to 30 feet each[1].

The finest example of limestone of the Old Red System in Caermarthenshire, occurs in the cliff under the Castle at Llanstephan near the mouth of the Towey. (Pl. 34. fig. 10.) The rock is there from twenty-five to thirty feet thick, the upper part consisting of a number of small concretions, which are underlaid by three massive beds of impure limestone, mottled green, blue, and red. Rising in a dome-shape and slightly inclined, this calcareous mass is overlaid by red and green marls; and further to the south or towards the marine headland, are flagstones, sandstones, and other well-characterized beds of the system. In a subsequent account of Pembrokeshire, I shall have occasion to show that although the calcareous matter becomes much scarcer in the Old Red Sandstone of that county, we still meet with mottled, imperfect, concretionary masses, which are in parts calcareous, and represent the cornstone formation.

To the east of Brecon, the cornstones rise from beneath the uppermost or quartzose strata into the escarpment of the mountains of the Black Forest, where they are much more strongly developed than in Caermarthenshire, as attested by different lines of lime-kilns which mark the lower limits of the mountains S. and S.E. of the town of Hay. (Pl. 31. fig. 1.) Some of the subordinate beds in the immediate vicinity of Hay, afford a most excellent, thick-bedded freestone of a delicate green colour, and of which the town is built. The cornstones, which are here so prevalent, rise to considerable heights on the sides of the escarpments, and dipping gradually to the south-east, occasionally reappear in deep denudations in the valley of the Usk, near Abergavenny; and finally disappear under the great mass of overlying sandstone and quartzose conglomerate, which has been described as forming the extreme margin of the South Welsh coal-field. At the northern escarpment of the Skirrid, the remarkable ridge to the north of Abergavenny before alluded to, thick beds of cornstone are exposed, dipping under red, brown, chocolate, and green sandstones, with blotches and concretions of red marl. Other courses of cornstone extend along the lower sides of the Skirrid, and are exposed in the transverse valley between that mountain and the Sugar Loaf; and a few thin

[1] The inhabitants of the banks of the Sowdde are not aware of the calcareous nature of these beds, there being no occasion to seek for lime in a situation where, from the high inclination of all the strata, the middle and lower members of the Old Red Sandstone are thrown into the immediate neighbourhood of the escarpment of the carboniferous limestone (see section Pl. 34. fig. 5.), the great works in which, at Clogan-mawr and Clogan-bach, on the road leading from Pont-ar-lleche to Swansea, supply all the adjoining western districts of Caermarthenshire with lime very superior in quality to any which can be procured from the cornstones of the Old Red Sandstone. The same statement may be applied to the district immediately to the north of Abergavenny, where the cornstones are exposed, but will not, from their impure quality, stand a competition with the adjacent carboniferous limestone, and consequently are not worked. (See Map.)

layers have been already alluded to as appearing in the face of the great escarpment of the Blorenge.

I refer the reader to the map to obtain a notion of the large tracts in Brecon and Monmouth, where these limestones prevail. A good descending section of the whole system of Old Red, has recently been laid open by making the new road from Chepstow to Usk, which runs directly across the strata. On this road, the traveller first passes over the quartzose formation of sandstone and conglomerate, rising from beneath the lower carboniferous limestone shale; next the marls and cornstone in the bold escarpment of Golden Hill, and thence traversing sundry calcareous courses, he meets with the Silurian Rocks in the hills north of Usk, throwing off upon their eastern slopes the marls and tilestones. (See Pl. 36. fig. 21.) In the southern parts of Herefordshire (between Monmouth Cap and Whitefield), are numerous courses of small round concretions, which not being firmly bound together by the matrix, readily separate from the imbedding sand and clay, and are used as gravel for the roads. In the same tract, however, are strong courses of very pure concretionary limestone, of purple and green colours, one variety of which appears to have been formerly used as marble.

To the north of the river Wye, the same system is prolonged in the central hills of Herefordshire; and traverses made across these hills from Hereford to the Vale of Weobly, afford good sections of the cornstone group. The descending section of it may be thus enumerated, the beds dipping to the S.E. or S.S.E. at angles of 12° and 15°.

*a.* Slaty beds, quarried for tiles in the hills above Mr. Peploe's Park, (contain broken portions of vegetables, often in a state of carbon).

*b.* Marls, red and green.

*c.* Cornstone, in parts semi-crystalline, seldom exceeding 4 to 5 feet in thickness.

*d.* Argillaceous marls with impure limestone, fit only for road-mending.

*e.* Great sandstone quarries (at Raven's Causeway, for example,) from 30 to 40 feet in depth, contain fine large flaggy beds of light greenish colour, used for tombstones; and strong beds of micaceous, finely-grained sandstone, the lines of deposit being sometimes marked by purple and light green stripes. This stone is of excellent quality for building.

*f.* Argillaceous marls.

*g.* Courses of impure concretionary limestone, appear here and there in the slopes and lower sides of the hills; these descend into the rich low grounds around Weobly. If powerful denudation had not destroyed the strata and covered them with gravel, the valley of the Wye between Hereford and the Hay would doubtlessly have afforded similar sections, for the same succession of argillaceous marl, sandstone, cornstone, and flagstone is displayed in the hills of Moccas on the south or right bank of the Wye, as those described in the Weobly Hills. There can, indeed, be no doubt that the strata of these two hilly ranges on the opposite banks of the river were once continuous, because whenever the gravel has been removed, the cliffs exhibit the red argillaceous beds.

Similar arrangements of strata are exhibited in the escarpments of all the hills extending from Weobly to Leominster, and thence to Tenbury and Bromyard; the vast thickness of the formation, including many masses of strong-bedded sandstone, being remarkably well displayed in the hills crossed by the new road from Leominster to Hereford. Wherever the marls have prevailed, the denudations have been most extensive, as is remarkably exemplified in the lateral valleys on the sides of the Pyons, two small conical hills, probably saved from destruction by the hardness of the concretionary rock and gritty sandstones near their summits.

Nearly the whole of the central and northern parts of Herefordshire, and the contiguous parts of Salop and Worcestershire, are occupied by this formation, those hills having best resisted denuding influences, which contain the hardest concretions of corn-

stone, or the firmest ribs of sandstone. In the northern portion of this range, the subordinate limestones become thicker and more crystalline.

Bands of cornstone appear at intervals in all the country lying between the Clee Hills and the southern extremity of the coal-field of Coalbrook Dale; the same suite of beds forms also the base upon which the greater part of the coal tracts of Billingsley and the Forest of Wyre have been deposited. At Lower Harcott, on the west side of Kinlett, the cornstone dips south and south-south-west forty-five degrees, is five or six feet thick, and is burnt for lime. It here reposes upon a good sandstone of greenish colour. This cornstone, as in other parts, is of very irregular dimensions, contracting and expanding in the most capricious manner. In one district only I have traced it on the east bank of the Severn, where the existence of the Old Red Sandstone had not previously been noted in geological maps. (See Map and Section, Pl. 30. fig. 3.)

The formation is there displayed in a narrow and detached ridge on the south side of the thin zone of coal measures of Arley and Shatterford, ranging between these rocks and the New Red Sandstone of Warshill and Horsley Bank near Kidderminster. The Old and New Red Sandstones are in abrupt and unconformable junction on the sides of a new cut in the road ascending from Kidderminster to Shatterford Gate, near which beds of true cornstone are burnt for lime. These beds are there clearly distinguishable from the calcareous bands of the adjacent Lower New Red Sandstone, by their unconformable position.

The extent of the changes made in the map of the boundary lines of previous observers, defining the junction of the Old, and the contiguous New Red Sandstone of Worcestershire, can be best understood by comparison with such authorities. Much ambiguity, indeed, prevailed in this part of the region, owing to the anomalous lithological characters of the Lower New Red Sandstone, (already explained in chapter 4.,) which, on the confines of Worcestershire, Salop, and Herefordshire, puts on so much the character of the Old Red, with which it is in contact.

On the right bank of the Teme, the hills of Old Red Sandstone, ranging from Tenbury to the villages of Stamford and Shelsley Walsall to Sapey, &c., consist of marls, clays, sandstones, and flags, with some thick zones of concretionary limestone. In one of these bands near Hill Top, east of Tenbury, I found the crevices partially filled with minute thin coats of anthracite, mixed with white crystallized carbonate of lime. Besides the principal bands of limestone, which here vary in thickness from four to ten feet, there are, as in other places, thinner courses of cornstone, alternating with beds of deep red and greenish sandstones, of a flaggy structure. Much calcareous matter is disseminated throughout these hills, and gives rise to the superficial deposit of travertine and stalactite which will be described in a subsequent Chapter. (See *Southstone Roch*, Index.)

The sandstones associated with the marls and cornstones sometimes expose upon their surfaces certain small depressions, frequently of circular and horse-shoe forms, occasionally having a raised central disc. These forms, which are remarkably exhibited in the bed of the Sapey Brook, near Knightsford Bridge, appear to be due to the action of water upon blotches, or imperfect concretions of party-coloured marls or soft argillaceous sandstones, which being of less consistence than the mass of the rock, have been eroded, leaving these cavities. Similar forms, indeed, are found in numberless portions

of the Old Red Sandstone. I may particularly cite the escarpment of the Skirrid, three miles north of Abergavenny, and the cliff called the Daren, north of Crickhowell, as situations where they may be seen in countless profusion, imitating in their outline, horse-shoes, rings, almonds, &c. It is quite manifest that by exposing rocks of the varied composition of these in question, to the action of running water, as in the Sapey Brook, or to long-continued atmospheric influences, as in the Skirrid, the inevitable result would be the wearing away of these blotches or concretions, which are softer than the inclosing mass of rock[1].

There is no district in which the nature and relations of the cornstone can be better studied than to the north of Ludlow, where the formation occupies a distinct range of hills rising to the height of four or five hundred feet above the low country, and presenting escarpments to the valley of Corvedale. In these hills are several calcareous zones, separated by thick masses of sandstone, flagstone, and argillaceous marl, the strata dipping slightly to the north and south of east.

Some of the best flagstones of these hills are quarried at Bouldon. The upper beds consist of red marl, impure cornstone, and thin beds of deep-coloured red sandstone. Beneath these lie about twelve feet of sandstone, which splits into flags. This stone is of a greenish colour and highly micaceous, and its surfaces are marked by those undulations or ripple-marks, so frequent in the sandstones of all ages, and which are supposed to have resulted from the action of water during the process of deposition. The flags are from three to eight inches thick, and sometimes of great extent, and they are largely used for staircases, doorways, wall tops, lintels, &c.; a course of impure cornstone underlies the flagstone. Similar flagstones but generally of dull red colours are extracted at the southern end of the Brown Clee, and on the south-western slopes of the Titterstone Clee. In the quarries of Sir W. Boughton, Bart., at Downton Hall, flags are often quarried of the great size of one hundred square feet.

A section of the strata between the slopes east of Downton Hall and the valley of Corvedale is seen by reference to Pl. 31. fig. 3., and the structure of these beds is already sufficiently explained to render unnecessary the encumbering of these pages with similar details in other places. The courses of concretionary limestone are as usual not continuous; on the contrary, they expand and diminish, disappearing and reappearing in their horizontal range.

Similar exhibitions of concretionary limestone wrap round the sides of the Clee Hills.

[1] I was indebted to Mr. Jabez Allies, of Worcester, for directing my attention to these forms in the stone of the Sapey Brook, and concerning which he read an ingenious antiquarian memoir before the Natural History Society of Worcester. In that paper, since published, he states the following tradition of the district. A mare and her foal having been stolen from St. Margaret of Audley, the patron of the adjacent chapelry of Sapey, the track of the stolen animal, and also of the *pattens* of the woman who led them down the bed of the brook, were by the wrath of Heaven left as ineffaceable marks of the impious crime. This is no doubt a monkish legend, in which a natural phenomenon was made preternatural, to work on the credulity of the age, and is worthy of being added to the story of St. Bridget of Whitby, who through her intercessions turned all the *snakes* of that district into stone, these snakes being the ammonites of the lias!

On the western face of the Titterstone Clee they rise to a great height both at and above Bitterly Court; they surround the Brown Clee, and are largely quarried at Abdon, Ditton, &c. It is not possible to include these cornstones under one mineralogical description. In most places they are of red and lightish green colours; in others, however, they are light brown with veins of dark chocolate and green, a variety of which in a highly crystalline form is extracted at Targrove, near Downton Hall. At Ditton, white and green colours prevail; at Bromsgrove the mass is brown, with light grey patches; while at intermediate places they consist of marl, limestone, and sandstone, irregularly concreted, and have the aspect of a conglomerate. In the last-mentioned form alone, they constitute the cornstones of the inhabitants, and in this state are quarried exclusively for the repairs of the roads, and are not burnt for lime. The best courses are, however, almost crystalline, and if polished might be considered not inelegant marble, though the concretions are usually too small to afford large slabs. In some of the great works at Ditton and Abdon there are two zones, the lowest and largest of which is quarried to a depth of twenty feet, in caverns under the slopes of the Brown Clee Hills. It is needless to mention other localities in this neighbourhood, for the formation here ranges over a very wide area. (See Map.)

Throughout the whole of its range, with the exception of the space between the coal-field and the older rocks of Caermarthenshire, and its protrusion through some of the poor coal-fields of Bewdley Forest, the strata of this cornstone group are very little inclined, an arrangement which might naturally have been looked for in the central parts of a basin or trough of large size. The spotted marls can never be distinguished, from those of the New Red Sandstone, except perhaps when they are separated from each other by beds of hard, micaceous sandstone. In districts where the argillaceous character exclusively predominates, there is some difficulty in persuading the inhabitants that they live upon the Old Red *Sandstone*; although that name when applied to the whole system is as unobjectionable as any in the nomenclature of geology.

Wherever the order of superposition is not apparent, the fragments of fossil fishes which occur in abundance throughout the cornstones[1], constitute the best distinction between this formation and the Lower New Red Sandstone which it so much resembles. These fishes, which will be described in a subsequent chapter, are of very peculiar forms, and their fragments being often of brilliant purple and blue colours, are excellent points of attraction for the eye of the geologist; since they present a strong contrast to the surrounding dull red and green matrix in which they are enveloped. (See Pl. 1 and 2., in which the fishes of the genera *Cephalaspis* and *Onchus* are figured.)

[1] The fishes of the cornstone formation were first discovered by Dr. Lloyd of Ludlow. (See Chapter on the Organic Remains of the Old Red Sandstone.)

3. *Tilestone.* (See Sections, Pl. 31. fig. 1. Pl. 33. figs. 4 and 7. and Pl. 34. figs. 1, 3, 5, 6, 7, 8, and 9. Pl. 36. figs. 5 and 8. and *g.* of wood-cut, p. 179.)

*Course of the Tilestone from Caermarthenshire, through Brecknockshire and Radnorshire into Shropshire.*

This lower division of the Old Red System, though of much smaller dimensions than the overlying formations, has very marked characters both in structure and fossil contents, and is very clearly defined by occupying a position in which it passes upwards into the cornstone and marls, and downwards into the Silurian rocks. In this relation it has been already alluded to at Pont-ar-lleche (*bridge on the tiles*), near Llangadock in Caermarthenshire, from whence it is seen to run in a nearly rectilinear course, from the Tri-chrûg on the south-west, to near Builth on the north-east, occupying the loftiest part of the escarpments of the wild tracts of Mynidd bwlch-y-groes and Mynidd Epynt, at heights of fifteen hundred and sixteen hundred feet. In this range, the tilestones are extensively quarried, and the strata, which are inclined at seventy and eighty degrees near Pont-ar-lleche, diminish to forty and forty-five degrees at the north-eastern end of the Mynidd Epynt, the dip being invariably to the south-east. After a great flexure on the Wye, to the east of Builth, the tilestones are again found in similar relations overlapping the Silurian rocks in the Begwm and Clyro Hills, Radnorshire, and extending thence to Kington in Herefordshire; in which part of their range they are much less inclined. (See Pl. 31. figs. 1 and 6, and Pl. 33. fig. 2.) Throughout their course from Caermarthenshire to Kington, the distinguishing beds are finely laminated, hard, reddish or green, micaceous, quartzose sandstones, which split into tiles. Although the greenish colours prevail, these beds are usually associated with reddish shale, and the decomposition of the mass uniformly produces a red soil, by which character alone the outline of the division is easily defined; being always clearly separable from the upper beds of the Silurian System, which decompose into a grey surface. In Shropshire and the contiguous parts of Herefordshire, this lower member of the Old Red System rarely occupies high ground, (except in the instance of the outlier of Clun Forest, hereafter to be described,) and being for the most part recumbent on the talus of the upper Silurian rocks, where the latter sink down into valleys, it is generally much obscured by alluvial detritus. In the gorge of the Teme, however, between Ludlow and Downton Castle, it is well laid open, particularly at a spot called the Tin Mill. (Pl. 31. fig. 2.) Flaglike, micaceous, dark red sandstone "Bur Stones" rise there at an angle of about fifteen degrees from beneath the red argillaceous marls of Oakley Park, and pass down into a lightish-coloured grey, yellowish, and greenish grey freestone, of which Downton Castle is built, which will presently be described as constituting the upper stratum of the Silurian System. Similar relations are visible at Ludlow, and at Richard's Castle to the south of Ludlow.

In this district, however, these lower red and yellowish beds, or "bur stones," are seldom so fissile as the "tile stones" described in South Wales. They occasionally contain a few organic remains, such as Avicula, and a small Lingula, both of new species, which will presently be described. In the Shropshire beds the remains of fishes prevail more than those of mollusca, including the *Dipterus macrolepidotus* (Sedgwick and Murchison), ichthyodorulites of the genus *Onchus*, and small bufonites the remains of palates of fishes. (See Pl. 1. fig. 2, 2 *a*. Pl. 3. and subsequent description of the shells and fishes of the Old Red System.)

In the southern parts of Caermarthenshire and in Pembrokeshire, the tilestones cannot be traced as a persistent zone, and the triple subdivision of the system can no longer be observed. Thus, in following the escarpment of the carboniferous limestones of Caermarthenshire to the low hills near the coast, we gradually lose the distinct traces of the red conglomerate below it. Beds of cornstone are very rarely to be detected in the central masses, and the tilestone of Middleton Park (between Llandeilo and Caermarthen) are the last well-defined examples of that variety of stone. At Black Pool and Castel Goylan near the mouth of the Towey the lower beds do not afford tilestones, but, on the contrary, are thick-bedded, slightly conglomerated, mottled, quartzose sandstones.

The previous sketch, however, of the lower member of the Old Red has been derived from numberless transverse sections, made between Pont-ar-lleche on the south-west and the environs of Ludlow on the north-east, being a distance of near ninety miles.

Reverting to the section at Pont-ar-lleche (Pl. 34. fig. 5.), the shale and cornstone are there underlaid by alternations of red and green sandstone, some of the lowest of which are the "Tilestones" which give the name to the bridge. Below these are other bands of a quartzose, deep red sandstone, indurated shale, and slightly conglomerate purplish brown sandstone, containing small pebbles of quartz, which gradually disappearing, the beds pass into the underlying grey Silurian rocks of the district. These conglomerate beds, though not seen at the base of the Old Red System in any other parts of its course between Caermarthenshire and Ludlow, are found in the same position in Pembrokeshire and at Thornbury, Gloucestershire. (See the chapters on Pembrokeshire and Tortworth.) Casts of Orthoceratites and other fossils occur in the finely laminated beds associated with the tilestones at Pont-ar-lleche, similar to those of other localities.

The transverse section of these beds afforded by the valley of the Cwm Dwr, between Trecastle and Llandovery, is of high interest. (Pl. 34. figs. 1 and 3.) Tilestones are here quarried rising at an angle of sixty degrees from beneath the marly and sandy beds of the cornstone group, the lower tilestones graduating downwards into the equivalent of the Ludlow rock. The uppermost beds are of a dark purple colour, their surface being covered by large plates of a grey mica, and here and there indented with certain impressions resembling those in the Old Red Sandstone of Scotland called "Kelpie's feet[1]." The lower beds, as worked on the steep acclivity west of the meeting-

[1] It is highly probable that the Arbroath pavement beds of the Old Red Sandstone of Scotland, will be found to correspond with the tilestone formation of South Wales.

house called Horeb Chapel, have their dip increased to sixty-five and seventy degrees, and are of greenish and grey colours, but these are again underlaid by other beds of a reddish colour, so that the whole of the tilestones are clearly subordinate to the Old Red System. The greenish beds split to an average thickness of three or four inches, are much jointed, and have frequently an imperfect slaty cleavage transverse to the bedding; they are highly charged with mica, both disseminated and in laminæ. The joints are for the most part vertical, and their faces are frequently coated with crystals of white quartz.

Organic remains are abundant, and indicate clearly the lines of deposit, whilst the transverse cleavage and the faces of the joints are strongly marked by sharp planes cutting obliquely through the fossil layers. The fossils consist of unpublished species of the following genera: *Arca*, *Avicula*, *Bellerophon*, *Cucullæa*, *Lingula*, *Orthoceras*, *Terebratula*, *Turbo*, *Turritella*, *Trochus*, with the *Tentaculites scalaris* (Schlotheim).

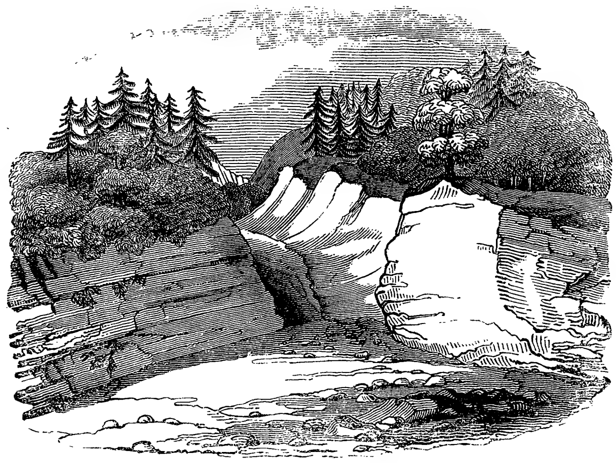
This assemblage furnishes convincing proofs that certain genera of mollusks, such as *Arca*, *Cucullæa*, *Turbo*, *Trochus*, &c., which have hitherto been supposed to be confined to the younger or tertiary and secondary deposits, have co-existed with the genera *Orthoceras*, *Terebratula*, *Bellerophon*, which peculiarly characterize the older strata. (See Pl. 3. and subsequent description of these fossils.)

*Tilestone Group, east side of Herefordshire.*—As the Old Red Sandstone lies in a vast trough bounded by the Silurian System both on its eastern and western flanks, we ought to find its lower member, or tilestones, forming the western fringe of the Malvern Hills. Owing, however, to high inclination, the accumulation of detritus, and other results of disturbance, these beds are rarely well displayed for any distance along the eastern frontier of the Herefordshire basin. They are, however, clearly laid bare in a natural transverse section at Brockhill Knell between Mathon and Ledbury, where thin bands of yellowish green, micaceous flagstone, one and two inches thick, are subordinate to red, green and purple marls, the whole dipping away to the west and overlying the grey Ludlow rocks at an angle of forty-five degrees. (See Pl. 36. fig. 7.) Hard and thin flaggy rocks belonging to this group are also seen at the north-eastern suburb of Ledbury, dipping fifty-five degrees west-north-west, but the flanks of the ledges of older rocks near that town are encumbered with so much stiff red clay and detritus that the exact junction beds can rarely be distinguished. (Pl. 37. fig. 8.) The same causes of obscuration, apply to the line of junction between the Old Red Sandstone and the Silurian rocks of the May Hill range. In some valleys of elevation, however, the upper surfaces of the grey-coloured Silurian Rocks, which are thrown up in their interior, exhibit on their external faces clear examples of passage into the bottom beds of the Old Red Sandstone. This is well seen on the eastern slopes of the Clytha Hills, two or three miles east of Ragland, and will be further alluded to in the sequel.

*Probable thickness of the Old Red Sandstone.*

The maximum thickness of the strata which compose the great British system of the Old Red Sandstone may best be computed by an examination of the various groups of rock which rise from beneath each other, between the edge of the South Welsh coal basin and the Silurian rocks of Radnorshire. In a space of about eleven miles, from the outlier of the carboniferous limestone called Pen Cerrig Calch near Crickhowel (see p. 163. and Pl. 31. fig. 1.), to the upper beds of the Ludlow rocks in the Clyro Hills west of Hay, all the intervening strata of the Old Red are conformably inclined and apparently without dislocations, at gentle angles of inclination, decreasing to five or six degrees as they approach the south-east boundary, and increasing to fifteen degrees as they rise towards the north-west or outcrop of the older rocks. In this wide space, there is no possibility of ambiguity or misconception, for the whole of the beds are successively exposed in lofty escarpments, which are clearly laid bare in the sides of the deep ravines by which the mountains of the Black Forest are fissured. The heights of these mountains vary from 1800 to 2500 feet.

Now provided the old notion were true, that strata preserved their dimensions on the dip and passed regularly beneath each other for great distances, there would be no difficulty in determining, by a simple trigonometrical calculation, the thickness of the Old Red System, which in this instance would be very enormous. But it is now a well ascertained geological datum that no such regularity exists, and therefore an attempt to deduce the vertical dimensions of formations, from their superficial breadth and the dip of the beds is no longer admissible. I think, however, that looking to the altitude of the mountains and the wide area they cover, the united thickness of the Old Red System, at a moderate calculation, cannot be less than nine or ten thousand feet.



## CHAPTER XV.

### OLD RED SYSTEM (*continued*).

*Trap-Dykes in the Old Red Sandstone; Mineral Veins; Dislocations; Outliers; Agricultural Characters of the System.*

TWO examples only are yet known of trap rocks within the wide area occupied by the Old Red Sandstone: the one at Bartestree near Hereford is marked in Mr. Greenough's map; the other, at Brockhill, on the left bank of the river Teme in Worcestershire, has not previously been noticed.

The Bartestree or Hereford trap dyke extends from west-south-west to east-north-east, as defined by the direction of its walls in the principal quarry called Low's Hill, where the stone has long been worked for the use of the roads. (See Map.) It is cut into to a depth of fifty feet, and a length of about a hundred and twenty feet. This excavated space is nearly sixty feet wide at its entrance, but the trap diminishes to about twenty feet in width at the extreme end of the quarry. The prevailing variety of the trap is a highly crystalline greenstone, made up of hornblende, olivine, and felspar. The central mass, having more or less the large spheroidal form, is hard and compact, with more hornblende than felspar, the mixture of these minerals being exceedingly intimate. Other portions of the dyke, particularly those which are near the sides, assume a prismatic form, the ends of the prisms directed towards the walls, and

contain much felspar and a little quartz, the exterior being coated with a substance having a greasy feel, probably serpentine. The rocks through which the dyke passes, consist of red sandstone and marl, belonging to the cornstone or central division of the Old Red System, and the beds at this spot are very nearly horizontal. The hard trap rock having been cut away, these horizontal strata are left on either side, their edges forming vertical walls, which were in contact with the dyke. We are here presented with an excellent illustration of the effects produced by intrusive trap, in altering or indurating the contiguous sandstone and marl through which it has passed ; for a purple amygdaloid, with kernels and nests of yellowish calcareous spar, forming the outer coat of the greenstone, is demonstrably nothing more than the spotted marls so altered by the action of heat, that they resemble trappean amygdaloids. The distinct separation of the calcareous from the argillaceous matter, and the diversity of the colours give to this rock a very peculiar aspect. The effect of these alterations is seen to penetrate beyond the amygdaloid several feet into the adjoining beds. In the sandstone, the grains of sand, the associated calcareous and argillaceous matter probably serving as a flux, have been fused into white quartz, much lime being diffused through the adjacent masses. Some of the carbonate of lime occurring in the nodules and veins, may doubtless in this, as in other cases, have been formed by infiltration, subsequent to the intrusion of the trap ; and I only mention the prevalent diffusion of calcareous matter through the mass, to indicate how essentially it may have contributed as a flux in the conversion of the rock. A few concretions in the altered marl are coated with crystals of pearl spar ("chaux carbonatée magnesifère primitive") arranged in globular forms. Other crystals have the aspect of dolomite, and thin films of anthracite appear here and there in the interstices, the volatile parts having been driven off by heat. At a few yards from the wall of the dyke, the strata of Old Red Sandstone resume their ordinary characters, and are nearly horizontal. The direction of this dyke of greenstone, from west-south-west to east-north-east, is remarkable in being at right angles to the axis of elevation of the adjoining Woolhope valley. It seems, however, to lie in the prolongation of the elevated mass of Ludlow Rocks called Shucknell Hill, distant three miles from this spot (see Map) ; and we may therefore infer that the dislocation of the strata of that hill was connected with a line of disturbance proceeding from the chain of the Malvern and Abberley Hills to Bartestree (see Description of Valley of Woolhope).

### *Trap-Dyke, Brockhill, Worcestershire* (Pl. 36. fig. 2., and vignette-head of this chapter).

This trap-dyke, so remarkable in mineral structure, has been exposed by quarries opened in a low hill close to the left bank of the river Teme, about eleven miles north-east of Worcester, and distant only one mile and a quarter from the western flank of

the Abberley Hills. It cuts through the Old Red Sandstone in a direction from five degrees north of west, to five degrees south of east; and being followed on its course towards the Abberley Hills, has been laid open to a depth of about forty feet. The trap is in one part about eight paces wide, and near its walls puts on a prismatic form, the edges of the joints of the columns decomposing precisely like those of the basalt of the Giant's Causeway, and some very regular columns have been extracted. The composition of the rock is unlike any I had previously seen in *basaltiform* dykes. It is in fact partly a dark green columnar *syenite*, made up of hornblende, flesh-coloured felspar and quartz, undistinguishable from varieties of the Malvern syenite; and partly an amygdaloid, containing kernels of carbonate of lime, which on exposure weather out and leave cavities on the sides of the prisms. A "sahlbande," a few inches thick, of a dark green colour, having a greasy feel, and being partially amygdaloidal, is interposed between the trap and the altered rocks. The sections on each side of the dyke exhibit horizontal beds, consisting of regular alternations of flaglike, micaceous sandstone and shale, with several courses, from one to four feet thick, of concretionary, spotted, impure limestone or *cornstone*. In contact with the trap, and for twenty feet and more from its walls, the sandstone is much hardened, mica is wanting, and the colour of the rock is changed to a dark purple. The variegated marls and cornstone are converted into an indurated mass like that of Bartestree, resembling many trappean amygdaloids: the lime is disseminated in veins and coatings of white crystallized carbonate of lime, with a few crystals of iron pyrites. Other varieties of these altered marls have a splintery conchoidal fracture, are partially prismatized, and have lost all traces of lamination. As this dyke is analogous in composition to some of the rocky prolongations of the Malvern ridge which extend to near Abberley[1], and as its course points directly to Woodbury, the most prominent of those elevations, we obtain one of the proofs that volcanic forces have been in activity along that great fissure of eruption subsequent to the consolidation of the Old Red Sandstone. Again, from the highly dislocated condition of the patches of coal, which adhere to the flanks of these hills, no doubt can remain, that volcanic action was also continued upon this line, after the deposit of the carboniferous system.

With the evidence we shall hereafter adduce of the frequency of trappean eruptions during the formation of the Silurian system, and with the proofs we have already given of the outburst of such rocks subsequent to the consolidation of the coal measures, Chapters 5 to 11, it is surprising, that during the accumulation of the widely expanded series of Old Red Sandstone, there should apparently have been a total cessation of the evolution of igneous matter; for the dykes we have just described must have been intruded after the old red strata were deposited. It is further well to remark in this place, that the prevalent horizontality of the great masses of Old Red Sandstone, in the counties

[1] See Map and subsequent Chapter on the Malvern and Abberley Hills.

of Brecon, Monmouth, and Hereford, is probably due to large tracts of this region not having been the theatre of those violent disturbances which have affected the Lower Silurian Rocks and the coal measures.

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## *Minerals in the Old Red Sandstone.*

The Old Red Sandstone does not contain any mineral veins worthy of notice. Even the ores of iron, which are more or less abundant in formations of every age, from the newest tertiary down to the carboniferous deposits included, never occur in distinct masses, though iron is the chief colouring matter, as well as cementing ingredient of all the rocks in the Old Red System.

This poverty in metallic veins is of great interest, when connected with the almost total absence of igneous or intrusive rocks, as just explained; for it will be shown elsewhere, that in those districts which abound with trap, both altered rocks, and metallic veins, are of common occurrence[1].

Throughout the whole of the great territory occupied by this System, I have met with only two examples of metalliferous veins, which have been deemed worthy of the slightest attention, and these are both of copper ore. One occurs at Hayton's-bent, in the escarpment of the cornstone Hills north of Ludlow, the other in Brecknockshire.

In the first case the works, which never produced any profits, have been abandoned for one hundred years; and as there are no records, the only information to be derived, is from the appearances at the mouths of the old trial shafts or galleries. From these we may infer, that the vein ran from N.E. to S.W., or nearly parallel to the strike of the beds, which are inclined very slightly to the S.E. Out of the refuse stuff, I collected several small specimens of green carbonate and grey copper, in a matrix of calcareous spar running in small veins through fragments of sandstone. The Brecon example is at Felin Fach, four miles north-east of the town of Brecon, and on the right bank of a mountain stream which descends from the Mynidd Llandefelle. The strata here, though containing no cornstone as in Shropshire, belong to the lower part of the same group, and consist of hard chocolate- and greenish-coloured sandstones, with a granular quartzose rock, the base of which is interspersed with bright pink grains of quartz, and a few blotches of green earth. Other bands of greenish grit have their surfaces speckled with brown, these differences of colour being probably dependent on the mutual presence of the silicate or the oxide of iron. The vein stuff thrown out from the trial shafts, (the works having been abandoned,) contains much crystallized carbonate of lime, chiefly of the primary rhomb, with sulphurets of copper and iron partially diffused through a mass, the remainder of which is made up of scales of green earth, crystallized blende (black jack of the miners), in very minute particles, and a little red oxide of iron.

Judging from these examples of slender and poor veins, and their entire absence in

[1] See particularly the chapter on the Shelve and Cornden tract, following the description of the Silurian Rocks in Shropshire.

the numerous bold escarpments, deep ravines, and fine natural sections with which the country abounds, we have inferred that the system contains no mineral ores worthy of economical attention. The presence of these copper veins in the Old Red is curious, as presenting an analogy to similar veins described as the chief mineral ore in the New Red Sandstone. If it be worthy of remark that these two Systems, so different in age, yet agreeing so much in their predominant colour and component parts, should contain the same metallic ores, we shall hereafter have occasion to see the phænomenon repeated a third and fourth time in sandstones of the Silurian and Cambrian Systems, the rocks in such cases being of the same red and green colours as in the New and Old Red Systems.

Shall we suppose that these coincidences are purely accidental, or that they have originated in a general cause? Although I have never reflected on them without being led to speculate on the hypothesis, that some portion of the matrix, common to all these red deposits, had been so operated on by heat, galvanic agency, or other cause of mineralization, that copper ores have been the result; still, as I am not aware that any chemist will yet venture to establish a theory founded on such data, and as we know that similar ores occur in other countries throughout strata of grey and other colours, as well as those of red and green, we must, I fear, remain contented with the simple announcement of the fact, until the chemical philosopher shall more particularly direct his powers to the subject.

As there are no metallic veins, so is there no coal in the Old Red Sandstone of this region. I have, indeed, previously shown, that there are not the smallest hopes of ever discovering a workable seam of coal within the area occupied by this system, because it never contains the vestiges of any quantity of vegetable matter out of which that mineral may have been formed[1].

*Dislocations.*—Some of the most prominent dislocations of the Old Red Sandstone, are those which appear on the northern and western edges of the south Welsh coal-field, and in the Clee Hills; in short, in the elevated tracts already described in the eighth and thirteenth chapters, where the Old Red Sandstone is seen supporting the carboniferous limestone and overlying coal-fields. One of the most powerful of these dislocations is probably that of the Caermarthenshire Fans, described p. 164, being an upcast of at least eight hundred feet. It has also been shown that the elevated coal tracts which lie in basins, have been fashioned into those forms by violent dislocations which have necessarily upturned the surrounding ledges of Old Red Sandstone, in common with the superposed carboniferous masses. The geologist will readily understand, that as such dislocations are generally transverse to the circular or elliptical edges of the coal-fields, the course of the faults must vary with every change of the strike, and

[1] On the borders of England and Scotland, principally on the northern banks of the Tweed, coal seams reoccur at intervals, not only through the whole of the carboniferous system, including the mountain limestone, but also partially beneath that formation, in the *upper member* of the Old Red System.

cannot have any one prevailing direction. Minor dislocations abound in this, as in all other old rocks, but they are less known than in the carboniferous system, because the entire absence of mineral productions has precluded mining operations, by which the extent of such faults is usually ascertained. The construction of new roads, however, occasionally lays them open, and a very instructive example is to be seen on the sides of the road south of Lydney near the Severn (see Pl. 30. fig. 13.), marking one of the dislocations which surround the coal basin of the Forest of Dean[1]. Other dislocations of the Old Red Sandstone are exposed on the edges of the Abberley and Malvern Hills (see Pl. 36. figs. 1, 2, &c.), and analogous phenomena will be described in the chapters upon the Pembroke and Tortworth districts. In the mean time, I will now direct attention to certain great outliers of the system which have escaped the notice of previous observers.

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### *Outliers of Old Red Sandstone—" Forest of Clun."* (Pl. 33. fig. 1.)

The outliers of Old Red Sandstone, which I proceed to describe, are separated from the great mass of that system by wide intervening tracts composed of Silurian rocks. The largest of these outliers is a considerable district of nearly one hundred square miles in superficial extent, and of which Clun Forest forms the principal part, surrounded by the towns of Newtown, Montgomery, Bishop Castle, Knighton, and Clun. The eastern boundary is upwards of ten miles and its western limits more than twenty miles from the edge of the great area of Old Red Sandstone. (See Map.) The whole of the soil of this detached district is red, and the beds beneath it are similar to those previously described as members of the Old Red System, whilst numerous natural sections show, that the grey-coloured masses which surround and support it at low angles of inclination, are the true Ludlow rocks. (See Pl. 33. fig. 1.) Clun Forest itself, is principally composed of the lower group of the Old Red, consisting of hard, thin-bedded, micaceous sandstones with argillaceous marls. These rocks are here known as "firestones" from their power of resisting heat. They are the only good building materials over an extensive tract, and are distinguished from the grey-coloured strata of the Silurian System on which they rest, to which the term of "greenstone[2]" is there universally applied. By traverses from Newton on the west to Knighton on the east, and across Kerry Hill to Bishop's Castle, and to Clun, I have ascertained that most of this "firestone" of Clun Forest represents the tilestone or lowest member of the Old Red; because it occupies the bottom of a large basin and, reposing upon, passes

[1] This and other faults of that region have been examined in great detail by Mr. Bragge Bathurst of Lydney Park, who has laid them down with much precision on a sheet of the Ordnance Survey.

[2] "Greenstone," i. e. a perishable stone. (See note in the ensuing chapter upon the Ludlow rocks.)

downwards into rocks containing, the characteristic fossils of the Ludlow formation. There are, however, overlying thicker-bedded sandstones and micaceous, red and green spotted marls, which are deeply cut into by ravines near Hall in the Forest, above Newcastle, also near Bettws, and these may be referred to the central members of the formation, though I never observed any traces of real cornstone[1]. The ridge of Silurian rocks in which the Teme rises, and which separates that river from the valley of the Ithon, is the southern prolongation of Kerry Hill, and is composed of grey-coloured masses, which offer numerous sections, proving them to belong to the Ludlow formation. The strata, dipping to the east, pass under the flaggy beds of Old Red, and contain many fossils, which, as will hereafter be shown, are characteristic of the upper Ludlow rock, and are never found either in older or younger formations. (See tabular view, locality, Felindre, &c.) From these beds of upper Ludlow rock, there is as true a passage upwards into the 'tilestone' or "firestone" beds, as any exhibited in Caermarthenshire, Brecknockshire, or Herefordshire. The passage beds near Felindre are hard, greenish, and reddish, highly micaceous sandstone, which contain the *Leptæna lata* and the *Terebratula Nucula* of the Ludlow rock (Pl. 5.), together with casts of several shells, identical with those found in the tilestones of the Cwm Dwr, Caermarthenshire, and which have never been found in the Silurian System below its junction with the Old Red Sandstone. These fossils are represented in Pl. 3, the lower part of which in particular, is occupied by figures of the remains occurring in the beds of passage between the Old Red and Silurian Systems. (See subsequent description of these fossils and some remarks thereon.) The casts of these fossils, though in a very fragile state, are beautifully preserved, the cavity between the mass of the rock and the casts of the shells being generally filled with a black powder, probably a mixture of silex and iron.

The tilestone beds, (firestone,) exhibit sometimes thin layers of matted and broken vegetable remains, frequently in a state of impure carbon. These vegetable fragments are found in quarries three miles north of Knighton on the road to Clun; and at Rhydcwm near Felindre. The plants are conjectured to be terrestrial, but are in too mutilated and broken a condition to be referred to any known genera, fossil or recent.

### *Outliers of Old Red Sandstone in Radnorshire.*

*Norton.*—The outlier next in magnitude to that of the Forest of Clun, is situated between Presteign and Knighton, and covers an area of about five square miles. This

[1] I am indebted to Mr. Mickleburgh, land-surveyor, of Montgomery, for much assistance in laying down the outline of this wild tract upon the map. Mr. Mickleburgh is most intimately acquainted with the diversity of soils; the natural drainage; in short, with the physical geography of his native county. I have had repeated occasions of testing this knowledge in the field, not only in the mountain tracts of the Forest of Clun, but also in the complicated and broken districts around Hyssington and Shelve.

mass is of an irregular oblong shape, being about four miles in length, from Oak Hill on the north-east, to Norton Ruralt on the south-west, and has an average width of about one mile and a quarter. On the north it is separated from the Old Red of Clun by the valley of the Teme and the bold ridges of Ludlow rocks forming Stow Hill, and on the east and south, it is completely cut off from the great area of Old Red Sandstone in Herefordshire, and from smaller outliers south of Presteign by other zones of Silurian rocks. The hills of this outlier vary from 800 to 1350 feet in height, and the surrounding elevations of Silurian rocks are pretty nearly of the same altitudes, Stow Hill alone attaining a height of 1417 feet (Trigonometrical station, Holloway rocks). At Reeves Hill, near the northern and north-eastern boundary, the strata occupying ground 1200 to 1300 feet high, dip south-east twenty degrees; at Norton in lower situations, north-east, and at Witley, north-west; so that the outlier occupies a basin which is of very irregular shape, owing to the dislocations and varied directions of the older rocks which surround it[1]. Flaglike firestones, similar to those of Clun Forest, are largely excavated at Reeves Hill, and thick-bedded red sandstones, of tolerably good building quality, at the quarries above Witley. The junctions of the Old Red with the Ludlow rocks are not often well displayed, but the latter are visible in many places near the former, dipping inwards, and therefore supporting this insulated mass. On the other hand there are apparent unconformable junctions, particularly to the west of Norton, doubtless produced by the dislocations which severed this outlier from the main tract of Old Red Sandstone, with which it must once have been continuous. Other separate but contiguous patches of Old Red Sandstone, cover the grey surface of the upper Silurian rocks, on the sides of the hills south of Knighton, but they are too thin and insignificant to be noticed.

There is a third outlier of Old Red Sandstone, about half a mile south-west of Presteign. This mass is of small size, merely occupying the western side of the Nash Scar ridge called 'Lower Radnor's Wood,' and extending into the lower grounds between that hill and Harley's Wood. The strata are there thrown up in vertical or highly inclined positions, with a strike from north-north-east to south-south-west, and consist of thin-bedded, micaceous sandstone, with deep red argillaceous marl. The relations of this dislocated mass of red sandstone to the contiguous Silurian rocks is explained in Pl. 33. fig. 2.

A fourth, and the last outlier I have occasion to notice, is also in Radnorshire, and lies to the south-east of the last-mentioned. It is likewise a narrow stripe, but is of much greater length than that of Lower Radnor's Wood, being continuous for about three miles from Weythell, south of Old Radnor, to Wernilla on the eastern flank of

[1] The position of the romantic cottage of Mr. R. Price, M.P., near Norton Ruralt, marks the extremity of one of the tongues of Old Red Sandstone which, peninsulated amid the Silurian rocks, indicate the irregular form of this outlier.

Colva Hill. In the farms of Llanhowel and Foyce, the strata rising into a low hill are vertical, and consist of greenish, red, and chocolate-coloured, thin-bedded, micaceous sandstones, flanked on the east, near Gladestry, by traces of impure cornstone and mottled concretionary marl. The direction of the ridge is from north-north-east to south-south-west, and the Silurian rocks which flank it, are parallel and also highly inclined.

We shall recur to the form, direction, and highly elevated position of these stripes of Old Red Sandstone to the south of Presteign in a subsequent chapter, after the intrusive rocks which have affected this district have been described. It is sufficient to state in this place, that beyond all doubt, these outliers have been separated from the chief mass of the system by elevatory forces, which erupting the igneous rocks, upheaved the inferior strata, and caused great denudation in the overlying deposits.

Wherever these outliers occur, the agricultural surface presents a marked contrast to that of the surrounding grey tracts of the Silurian System, being in fact repetitions on a small scale of the large basin occupied by the Old Red System.

### *Agricultural Characters of the Old Red Sandstone.*

The decomposition of strata so different in character as those which constitute this system, naturally gives rise to soils of dissimilar qualities. In those high and mountainous tracts which are principally occupied by the upper formation of quartzose conglomerate and sandstones, the soil is light, sharp, and little productive. In the cornstone group, on the contrary, the disintegration of calcareous nodules, and the admixture of their component parts with the argillaceous and sandy particles of the other strata, produce the well-known, rich, red soil of Herefordshire, in the greater part of which an argillaceous character prevails. The most loamy of these marls afford the finest crops of wheat and hops, and bear the most prolific apple and pear trees; whilst the whole region (eminently in the heavier clayey tracts) is renowned for the production of the sturdiest oaks, which so abound as to be styled the "weeds of Herefordshire." Thus, although this region contains no mines, the composition of its rocks is directly productive of its great agricultural wealth.

As some of the characters here described, are also common to the lands of the *New* Red Sandstone, so in that case, are the results due, to the decomposition of rocks similar in structure to those of the Old Red; for it has been previously indicated, that the spotted marls and concretionary limestones of the two systems are often undistinguishable. (See Chapters 3 and 4.)

The concretionary limestones are so abundant, that there is scarcely any part of the central districts of Herefordshire where lime-kilns are not numerous. But this lime, being itself much impregnated with argillaceous matter, is not always well adapted to the soil, particularly where the clays prevail; and hence whenever the inhabitants lie

within reach of the *carboniferous* limestone, they have found that variety of lime better suited for agricultural purposes, doubtless owing to its being less impregnated with earthy impurities.

The tracts situated upon the lower member of the System, though not generally of so rich a character as those of the cornstone formation, are yet not so sterile as those of the upper sandstones, for in those districts where argillaceous matter prevails we find stripes of valuable land. Hence although nearly every portion of the area coloured in the map as Old Red Sandstone has a *red* surface, the quality of the soil is as various as the many-featured strata which lie beneath it[1].

Another cause of diversity in agricultural value, though not connected always with the Old Red System, consists in local superficial coverings of gravel and silt. In some cases, indeed, whole tracts are sterilized by a distribution of bowlder stones and coarse gravel, made up of Silurian and trap rocks, which have been transported from the west and north-west; while in others the finer gravel, is the bearer of excellent crops, and the deep red silt forms plains of rich meadow ground. These features will be further dwelt upon in the concluding chapters, when we come to speak of the alluvial and diluvial phenomena.

Water is found at various levels and of very different degrees of purity. In some of the heavy argillaceous districts, it is slightly saturated with red particles, yet I never heard of any deleterious effects arising from its use, and where beds of cornstone and sandstone prevail it is as clear as in any country.

[1] The principal exceptions to red colour, occur at Prescot Bridge, Salop; in parts near Bromyard, and in certain districts of Pembrokeshire.

Lady H[t] Clive del.

Titterstone Clee

Day & Haghe Zinc[o]

LUDLOW.

# CHAPTER XVI.

## SILURIAN SYSTEM.

WE have at length reached those older deposits, which not having been separated into formations by previous writers, I am compelled to describe under new terms.

Acting upon the principle which guided William Smith in subdividing the oolitic system of our island, I have named these rocks from places in England and Wales, where their succession and age are best proved by order of superposition and imbedded organic remains, and have termed them in descending order, the "Ludlow", "Wenlock", "Caradoc", and "Llandeilo" formations. The same principle has led me to use the general term of Silurian System for the group, to mark thereby the territory in which the best types and the clearest relations are exhibited[1].

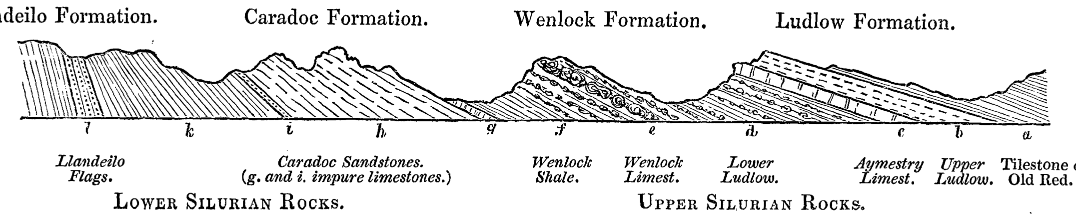
Like every other mass of strata entitled to the name of System, the Silurian, though clearly recognisable as a whole over extensive tracts, cannot always be subdivided into those formations which are displayed in the regions where I shall first describe it, and where its types are fully developed. Thus, for example, where the subordinate limestones thin out and disappear, the Ludlow deposit can seldom be clearly separated from that of Wenlock. In such cases both these formations are included in the term of "Upper Silurian Rocks", and under similar circumstances the Caradoc sandstones and Llandeilo flags, in that of "Lower Silurian Rocks".

Simple as this classification may now appear, those versed in practical geology can well understand what must have been the amount of examination employed in its perfect establishment. To comprehend the extent of the break in the history of the older strata which has been filled up by the study and classification of these rocks, the student has only to refer to the tabular view I have prepared, and compare it with other tables framed upon an antecedent state of geological knowledge. He will then perceive, that what is here presented to him, as a well-ordered succession of great thickness, (each subdi-

[1] The country occupied by this system embraces large tracts of England and Wales, the principal part of which was included in the ancient British kingdom, of the Silures: hence the name I have selected. See introductory chapter; Appendix; and Table of Superposition. In the latter, the names of the overlying formations are printed in ordinary characters, whilst those of the older rocks, to which new names have been assigned, are in italics.

vision of rocks being characterized by a corresponding suite of organic remains), was formerly considered one assemblage, without definite sequence, and included under the unmeaning names of greywacke or transition limestone[1]. I have already explained that the latter term has been as liberally bestowed (chiefly, however, by foreigners) upon the carboniferous limestone, from which the Silurian rocks are separated by that enormous accumulation, the Old Red Sandstone; whilst the organic remains of both these systems are entirely dissimilar from those of the carboniferous æra. Referring to the introductory chapter for further explanation, let us now proceed to consider these Silurian deposits in the natural order in which they appear in the south-west of Salop and adjacent parts of Hereford.

22.




Upper Silurian Rocks.—1st formation, '*Ludlow Rocks*'. (Pl. 31. fig. 2. and *b. c. d.* of this wood-cut.)

The grey-coloured strata to which the name of "Ludlow rocks" has been applied, rise from beneath the Old Red Sandstone into separate mountain ridges and occupy a large portion of the area distinguished in the map by the light purple colour[2]. Examples of this order of infraposition are exposed in numberless natural sections which cross this zone of rocks between the hills near Ludlow on the north-east, and the sea-cliffs constituting the south-western extremity of Pembrokeshire, a distance of about one hundred and fifty miles. The term of "Ludlow rocks" has been selected, because the town of Ludlow is built upon the upper beds, near their junction with the Old Red Sandstone; the neighbourhood affording great facilities for studying the other divisions of the formation, as well as those older deposits which succeed beneath it. To the west, north-west, and south-west of Ludlow, these rocks rise into hills, the highest of which are about eleven hundred feet above the sea. The uppermost strata slope down into the lower country of Old Red Sandstone, while the inferior beds are well exposed in deeply channelled and broken escarpments. By this arrangement of the strata, and

[1] See the first, or Introductory Chapter.

[2] The formations composing the Silurian System are distinguished on the *map* by different *letters*, as well as by different *colours*. The letter *n* marks the Ludlow formation; viz. *n*. Upper Ludlow; *n'*. Aymestry limestone; *n''*. Lower Ludlow. The letter *o* marks the Wenlock formation; viz. *o*. Wenlock limestone; *o'*. Wenlock shale. The Caradoc formation is indicated by *p*; the Llandeilo by *q*. The double letters *n*+*o* represent the Upper Silurian Rocks, and *p*+*q* the Lower Silurian, where the subdivisions cannot be traced.

their varied directions caused by elevations to which we shall presently allude, the formation can be studied in detail, and hence we learn that it is divisible into three parts, each distinguished by characteristic organic remains. These subdivisions I have termed

1. *Upper Ludlow Rock.*
2. *Aymestry Limestone.*
3. *Lower Ludlow Rock.*

Although a common lithological aspect and colour pervade the strata of the formation, this triple subdivision is clearly observable throughout a large tract of Shropshire and Herefordshire, extending in a mass of flexuous form, from Aymestry by Ludlow to Onnibury, including the hills of Mocktree Forest; and afterwards in a range of hills lying between the red land of Corvedale and the straight ridge called Wenlock Edge. The Ludlow rocks of this district will be first described, and then the older formations which emerge from beneath them.

*Upper Ludlow Rock* (*b* of wood-cut).—This subdivision of the Ludlow formation consists essentially of thin-bedded, lightly coloured, and very slightly micaceous sandstones, in some parts highly argillaceous, and in others so calcareous as to assume the character of impure limestones. When deeply cut into, these beds are of greenish grey or bluish grey tints, but they rapidly weather to an ashen or more rarely to a rusty-brown colour.

The upper beds, forming the downward passage from the Old Red System, are yellowish sandstones, of a very fine grain and slightly micaceous. They are best displayed at Ludford, Richard's Castle, and on both banks of the Teme near Downton Castle (Tin Mill, &c.), where they are extensively quarried for flags and wall-building, and pass down into a greyish-coloured stone, of which Downton Castle is built.

Among the fossils of these upper beds is the small *Lingula cornea*, (Pl. 3. fig. 3.), sometimes having the nacre of the shell preserved, with fragments of carbonized vegetables, too imperfect to be generically determined, but probably of terrestrial origin. Small, black, polished, round bodies, the *bufonites* of old authors (portions of the palates of fishes), are not unfrequent. As the *Lingula cornea* occurs in the tilestones of the Old Red Sandstone, these strata might be also assigned to the same System. They are, however, beds of passage, which cannot be arbitrarily referred either to the Old Red or Silurian Systems. This yellowish rock is exhibited in several other parts of the district, as at Ashley Moor, Linton Lane, and North Field, near Mortimer's Cross, in most of which situations it is observed dipping under the Old Red Sandstone, and graduating downwards into the greenish grey strata of the Upper Ludlow rock.

Sections at Richard's Castle expose these transition beds. The principal part of the village stands upon a red micaceous sandstone, with much clay; and rising from beneath this into higher grounds on the north-west, at an angle of about 18°, the following beds are successively laid open, either in quarries or by the natural outcrop of the rock.

| | | Ft. | In. |
|---|---|---|---|
| *a.* | Red and yellowish Sandstone, covered and underlaid by red shale | 5 | 0 |
| *b.* | Yellowish Sandstone, somewhat micaceous (a good freestone) | 3 | 0 |
| *c.* | Ditto ditto more highly micaceous | 2 | 0 |
| *d.* | Ditto ditto | 4 | 0 |
| *e.* | Thin yellow flag or tilestones, with much carbonaceous matter and ripple-marks on surface. In the lower part they have little mica, become blue-hearted, and pass downwards into the greenish grey Downton-castle stone. | | |

The manner in which these beds overlie and graduate into the true upper Ludlow rock is well seen in the cliffs between the old and new bridges. Proceeding from east to west, the following strata are met with in descending order.

| | | Ft. | In. |
|---|---|---|---|
| | Yellowish and brown, flag-like, micaceous sandstone, with small Lingulæ, &c., as before described. (Ludford House is built upon them; they are the bottom beds of the quarry at Richard's Castle, or beds of passage into the Old Red Sandstone.) ..........10 to | 12 | 0 |
| 1. | *Downton-castle building stone*; greenish grey, slightly micaceous Sandstone, in beds from 2 to 4 inches thick, containing a few organic remains, such as *Leptæna lata* .........12 to | 14 | 0 |
| 2. | *Fish-bed.* The upper and lower parts consist of very finely laminated, argillaceous, greenish grey sandstone, containing here and there a few fish scales, with abundance of other organic remains, peculiar to the upper Ludlow rock, such as the characteristic shells represented in Pl. 5., viz. *Leptæna lata*, fig. 13.; *Orbicula rugata*, fig. 11; *Cypricardia amygdalina*, fig. 2.; *Trochus helicites*, fig. 5.; *Avicula lineata*, fig. 10.; *Bellerophon globatus*, Pl. 3. fig. 15, with zoophytic remains[1] ..........8 to | 10 | 0 |

The beds 1. and 2. are best seen in a low cliff on the west side of Ludford turnpike gate.

The central part of this stratum, which seldom exceeds two or three inches in thickness, and occasionally dwindles to a quarter of an inch, running out into thin embranchments, is a matted mass of scales, ichthyodorulites, jaws, teeth, and coprolites of fishes. These, together with a few small testacea, are united by a gingerbread-coloured cement, in which varying proportions of carbonate of lime, iron, phosphate of lime, and bitumen, are disseminated. Many of the imbedded fragments are of a jet black colour and high polish; others of a deep mahogany hue. So brilliantly black are many of the organic fragments, that when discovered, this bed conveyed the impression, that it inclosed a triturated heap of black beetles cemented in a rusty ferruginous paste. This bed was first made known by laying open the rock for the foundation of a house at Ludford, and might have escaped notice without the vigilant attention of my friends Dr. Lloyd and the Rev. T. T. Lewis. I have since traced it in other contiguous spots in the cliffs opposite Ludlow, and Mr. R. W. Evans of Kingsland has worked out its contents with great zeal, and has discovered other remains of fishes in the overlying and underlying strata, to which I shall allude in the sequel. This bone bed is not merely local, since fragments having the same structure, but of greater thickness than

[1] All the organic remains of the Silurian System will be described in a subsequent chapter, following the description of the fossils of the Old Red System. This arrangement, which will have the advantage of easy comparison and reference, has indeed been rendered imperative, from the delays attending the completion of the plates. *The organic remains mentioned in the text, are a few only of the most common species.*

any at Ludford, have been found near Richard's Castle; and there is every reason to believe that it extends through various parts of the Ludlow promontory. Nearly all the organic remains found in this singular little bed are figured in Pl. 4., and the specific characters of the ichthyolite, to which many of them belong, are described in the subsequent pages by M. Agassiz. The coprolites will be also described in the same place. Of these bodies, I would here only observe, that their form, colour, and association with fish-bones, naturally led to the opinion of their origin, which has been completely established by the analysis of Dr. Prout.

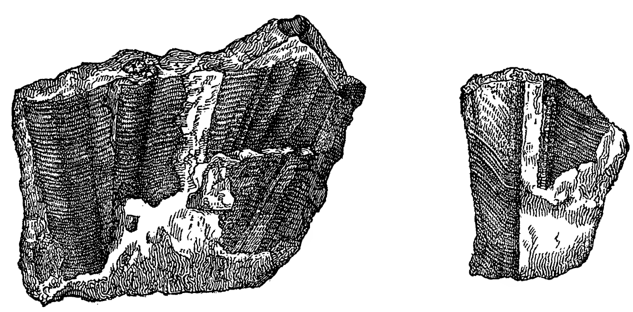
4. *Fucoid Bed.* This bed of greenish grey, argillaceous Sandstone is almost entirely made up of a multitude of small, wavy, rounded, stem-like forms, which so completely resemble entangled sea-weed, as to induce the conjecture, that they must be the impressions of such vegetables. The fucoid bed is also distinguished by containing what are supposed to be columns of some soft zoophyte. They are frequently found in positions which seem to throw light upon the mode of their interment; for the columns, occasionally some inches in length, are often found in vertical positions, and so standing up surrounded by the fine laminæ of the rock as to suggest the idea that whilst the lower part of the animal was attached, the sediment accumulated around the stem[1]. (See wood-cut below.)

The columns of this zoophyte are often found on the faces of the highly inclined and vertical joints which so prevail in the Ludlow formation, and which will be described hereafter. Most of these remains occurring just below the bone bed, and the harder portions of them being often found in the fossil fæces of the fishes, we are thus furnished with an additional argument in favour of the belief, that the zoophytes may have been in their natural positions, while the fishes fed upon their edible parts, occasionally swallowing portions of the harder columns of the animal, such as are now occasionally found in the centre of the coprolites.

Whatever value may be attached to these conjectures, the disposition of the animal remains, when coupled with the finely levigated nature of the inclosing sediment, tend at all events to sanction the belief, that the period of the accumulation must have been one of great tranquillity. Remains of analogous animals and portions of true Crinoidea, have been detected in other layers of the formation, but they are most abundant in and about the fucoid bed.

[1] The copper-plates in which the organic remains of this formation are represented, being filled with figures of other forms, and these fossils having been accidentally omitted, I offer a rough sketch of them in this woodcut. A further account will appear in the chapter on the organic remains of the formation.

23.



The strata above described compose the highest stage of the Upper Ludlow Rocks, which member, while it contains a few of the most common Testacea of the subdivision, is specially characterized by the abundance of remains of fishes, which are not rigidly confined to the "bone bed", but are occasionally found in other layers both above and below it.

The second stage or central mass of the Upper Ludlow Rock, is made up of strata containing less sand and more calcareous matter than the overlying beds, mixed up with the argillaceous paste; and though used for building, they are, from the prevalence of the argillaceous matter, generally prone to decomposition. When, however, used immediately after extraction from the quarry, and laid horizontally, or in the direction of the laminæ, these stones are tolerably durable, particularly when calcareous matter prevails, some of them being even impure limestones. Though they do not furnish flagstones, yet they are uniformly thin-bedded, the best stone when quarried never exceeding eight inches in thickness. (These strata appear in the foreground of the drawing by Lady Harriet Clive, prefixed to this chapter, and the castle of Ludlow stands upon them.)

The surface of the beds is sometimes covered by wavy undulating ridges and furrows, which are occasionally crossed by little raised tortuous bands. The ridges and furrows are supposed to be due to the rippling action of waves, when the bed formed the surface-bottom of the sea, and while the sediment was soft. The smaller transverse bands so much resemble the marks made by animals which live at present in sandy shores, as to induce the belief that many of the marks on these ancient rocks may have had a similar origin. It is chiefly in this portion of the Upper Ludlow Rock that the best testaceous and crustaceous remains are found, usually preserving all the sharpness of their form, and frequently exhibiting the remains of the original shell. Besides the *Leptæna lata*, *Cypricardia amygdalina*, *Orbicula rugata*, and *Avicula lineata*, already mentioned as occurring in the superior strata, these beds contain also many other shells, of which the *Orthis orbicularis* and *O. lunata* Pl. 5. figs. 15 and 16, *Terebratula Nucula* fig. 8, are the most characteristic. We here see, and in abundance, the very peculiar form *Serpuloides? longissima* Pl. 5. fig. 1, often extending itself in segments of large circles; and also two species of the *Homalonotus*, that singular genus of crustaceans, hitherto noticed only in the Ludlow formation, *Homalonotus Knightii* (König) and *H. Ludensis* nobis Pl. 7. figs. 1, 2, 3 and 4. *Orthoceratites* are abundant, particularly *Orthoceras striatum* Pl. 5. fig. 27. Some beds contain a small species of *Turbo* (*T. corallii*), so named because it is frequently invested by a small coral (*Favosites fibrosa*, Goldfuss). I shall show in a subsequent chapter to what great distances this shell and *Turbo carinatus* fig. 28. are found associated with the same coralline envelope.

The third or lowest stage of the Upper Ludlow Rock is distinguished from the overlying mass in being more argillaceous, less micaceous, and by occasionally running into large spheroidal concretionary forms. Being very slightly coherent and easily decom-

posing under atmospheric influence, it is well entitled to the name of "mudstone," which in other tracts is applied to large masses of upper Silurian rocks[1]. Like all the members of the Ludlow formation, these beds are traversed by many joints, more or less vertical, which will be described under a separate head. They are mentioned here to show, that their highly inclined or vertical faces are often marked by lines of small, round, or elliptic cavities (like swallow holes), from three to five inches long, and from one to two inches high. These cavities have clearly once been concretions which ranged along the lines of deposit like the flints in chalk, but in this case, unlike the pure and indestructible flint, the matter of which they have been composed, consisting entirely of a sandy clay, has separated from the harder portions of the rock, and has more easily disintegrated. These beds are less abundantly charged with organic remains than the overlying stages before described, though we meet at intervals with an orthoceratite or one of the above-mentioned characteristic fossils. The lowest stratum, however, of the upper Ludlow is very remarkable, being absolutely loaded with a vast number of small Terebratulæ of a gryphoid form, named *Terebratula Navicula*, Pl. 5. fig. 17. This shell is seen in abundance in the escarpments at the View Edge, Mocktree Forest, Downton on the Rock, at various places around the Ludlow promontory, and at Aymestry, always occupying the lowest portion of the Upper Ludlow Rock, and forming the cap of the calcareous zone of Aymestry. In some sections, these terebratulite beds attain a thickness of thirty to forty feet. This shell is of great geological value, as we shall see hereafter, being extremely persistent, and marking always the same horizon even to a distance of nearly one hundred miles. The beds which it occupies are sometimes so calcareous, and pass so naturally into the Aymestry limestone, that they may in all such cases be grouped with that rock.

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*Aymestry Limestone.*—(Pl. 31, figs. 2, 3, 4 & 5. and *c.* of wood-cut, p. 196.)

(See Vignette, chap. 20.)

The central member of the Ludlow Rocks is a subcrystalline, argillaceous limestone, which might have been termed the Ludlow Limestone; but as there are few good examples near that town, I have preferred naming it after the beautiful village of Aymestry, where the rock is fully and clearly laid open, and where its fossil contents have been elaborately worked out by my friend the Rev. T. T. Lewis[2]. It is there arranged in beds

[1] See note, page 204.

[2] The application of his leisure hours to the cultivation of the natural history of his neighbourhood may one day enable Mr. Lewis to confer upon Aymestry the celebrity which White has bequeathed to Selborne. Although this Aymestry limestone is splendidly exhibited in the narrow gorge of the Teme, under Downton on the Rock, in the picturesque demesne of Mr. Thomas Andrew Knight, that place could not have been selected for the name

from one to five feet thick, dipping to the south and south-east at slight angles; the laminæ of deposit being marked by layers of shells and sometimes of corallines. When quarried into, the rock is of an indigo or bluish grey colour, in parts mottled by the mixture of white carbonate of lime, both crystalline and compact. The quarries, like those in all the other rocks of the Ludlow formation, present natural backs more or less vertical, usually coated by a dirty yellow or greenish shale. The faces of these joints usually exhibit lines of small cavities similar to those already described in the upper Ludlow rock. When first laid bare in quarries, they have often a weathered aspect, which we may account for by supposing that they have for a long time been permeable to water.

This limestone constitutes the prominent and frequently the highest part of the escarpment of the Ludlow formation, in those hills which, beginning at Sutton near Wenlock, rise into the elevated ridges extending by Larden and Siefton to Mocktree Forest. It also forms the highest edges of the opposite escarpments of the Ludlow promontory. (See Pl. 31. fig. 5.)

Throughout this range, these calcareous beds are variously inclined according to the positions into which the Ludlow formation has been thrown. The prevailing inclination is small, but there are many marked exceptions to this arrangement, particularly around the Ludlow promontory. These will be more specially alluded to in the nineteenth chapter, when the dislocations of the strata are described.

In nearly all the quarries situated between Norton Camp and Aymestry, the rock is charged with a profusion of that remarkable shell called the *Pentamerus Knightii.* (Pl. 6. fig. 8.) This species is confined almost exclusively to the limestone of this subdivision, having never been found in the Upper, and very sparingly in the Lower Ludlow Rock[1]. The following fossils also characterize the calcareous zone: *Lingula Lewisii,* Pl. 6. fig. 9; *Terebratula Wilsoni,* fig. 7; *Bellerophon Aymestriensis,* fig. 12; *Avicula reticulata,* fig. 3; and the corals *Favosites Gothlandica,* &c. These fossils, with the *Atrypa affinis* (*Terebratula affinis,* Min. Con.) Pl. 6. fig. 5, serve to mark the course of the central subdivision of the Ludlow formation where the *Pentamerus Knightii* disappears. I have before observed that the cap of the limestone is charged with the *Terebratula Navicula* (Pl. 5. fig. 17.).

In the range of hills north of the river Onny, this limestone is principally worked at Dinchope and at Norton Camp. At the former place it appears as several undulating and disrupted masses,

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of the limestone without producing confusion, since in the same district there is another place called Downton, the seat of Sir W. Boughton, Bart., which, as we have seen, is the site of limestones in the Old Red Sandstone. The Aymestry limestone, as will hereafter be shown, occurs at Sedgely in Staffordshire, where it is largely used; but a name derived from a distant outlier, the relations of which could not have been established without the evidences we are now considering, is quite inadmissible.

[1] A single specimen of this shell has been detected in the Wenlock limestone of Nash, near Presteign, by Mr. Davies. (See chapters on Radnorshire and the organic remains.)

the beds dipping to the south-east and west-south-west at angles varying from ten to twenty-five degrees. The *Pentamerus Knightii* does not occur here, but the prevalent associated fossils, such as *Lingula Lewisii, Terebratula Wilsoni,* and others, are abundant. In Norton Camp, the limestone occupies a bold scar on the left bank of the Onny, the crest of which is about seven hundred feet above the river, in which position it forms an escarpment capping the lower Ludlow Rock; whence dipping to the south-east at an angle of 12°, it passes beneath the upper Ludlow Rock near Onnibury. The *Pentamerus Knightii,* though of rare occurrence to the north of the Onny, has been detected in the limestone of Norton Camp, associated with a few crinoidal stems, the *Productus lineatus,* &c.

In the View Edge, the cliff on the south bank of the Onny and opposite to Norton Camp, the limestone on the contrary is loaded with Pentameri, the shells packed closely together in a mass of limestone from nine to ten feet thick. Throughout its range, extending from this picturesque cliff to Aymestry, a devious and broken course of twelve or fourteen miles, the rock is everywhere characterized by the presence of the same beautiful fossil. Instructive sections are displayed at Goat's Hill, Shelderton, and Mocktree Hays, where masses of limestone, varying in thickness from fifteen to fifty feet, are uniformly capped by the terebratulite stratum, and repose upon the argillaceous beds of the lower Ludlow Rock. The new road from Ludlow to Leintwardine, traversing this escarpment, lays open a fine example of the limestone, which is there much worked, and has afforded the largest specimens of the *Pentamerus Knightii* yet found. In the gorge of the Teme at Downton on the Rock, the limestone is still better displayed in a vertical cliff, the beds of which dip at an angle of about twenty-five degrees to the north. The calcareous mass at this spot has a thickness of at least fifty feet[1]. The limestone can be further traced all round the inner edge of the great promontory of Ludlow. In Brindgwood Chase and Whitcliffe, it is only a thin band, which, turning round by St. Mary's Knoll, reappears in Sunny Hill Bank, and on the slope on Hanway Common, at the Bone Well, and at Palmer's Cairn. On the south-eastern face of this promontory it is thrown up into a double ridge, the inner one extending from the High Vinnall to Gatley Coppice, the outer continuous from the Palmer's Cairn to the Whiteway Head, and Croft Ambrey, and thence to the gorge at Aymestry by which the Lugg escapes into the plains of Herefordshire. At Aymestry it occupies both banks of that river, but it is chiefly quarried on the right bank and close to the village. The zone of limestone is not traceable for more than one mile to the south-west of Aymestry, where it thins into a narrow band and disappears beneath the mass of upper Ludlow Rock in the Hills of Shobden.

In their range over other and distant districts, the strata occupying the centre of the Ludlow formation are seldom sufficiently calcareous to be burnt for lime, and with the disappearance of the lime we lose the presence of the *Pentamerus Knightii.* The place, however, of this band is often clearly marked by the constant occurrence of the other associated fossils, particularly the *Terebratula Nucula,* the *Terebratula Wilsoni,* the *Lingula Lewisii,* &c. At Sedgeley in Staffordshire, however, where the rock again appears in a highly calcareous form, it will be shown to contain the *Pentamerus Knightii* of this western region.

[1] Large and massive blocks have been extracted by Mr. T. A. Knight, of Downton Castle, some of which have been polished as marble.

The Aymestry limestone differs in lithological aspect and useful properties, from any overlying or underlying calcareous rocks, being infinitely less crystalline and pure than the mountain or carboniferous limestone, and inferior in quality, though not in the same degree, to the lower limestone of Wenlock. Again, the Aymestry rock, partaking of the predominant character of the Ludlow formation, is for the most part flat-bedded, and is, on the whole, much less concretionary than the limestone of Wenlock. Its earthy character renders it, however, of very great value as a *cement*, particularly in subaqueous operations, and in ceiling and plastering, the mortar which is made of it setting rapidly under water. I have not observed any simple minerals in the Aymestry limestone, except crystals of carbonate of lime, and very rarely of sulphate of barytes. In the dislocated quarries on Mocktree Hays, and also at Aymestry, black siliceous and cherty matter sometimes penetrates the interior casts of the fossils.

*Lower Ludlow Rock.* (Pl. 31. figs. 2, 3, 4, and 5. and *d.* of wood-cut p. 196.).

The strata distinguished by this name are seen in the lower parts of the escarpments, underlying the Aymestry limestone. They differ from those of the upper Ludlow Rock, in being more argillaceous, less sandy and calcareous, with rarely a trace of mica. They constitute, in fact, a great argillaceous mass, strictly entitled to the provincial name of "mudstone[1]." The colours vary from light to dark grey and black; but whatever may be the tints of the rock when first quarried, it usually weathers to the same light ashen colour which is seen all over the surface of the Upper Silurian Rocks. The beds immediately beneath the Aymestry limestone, are occasionally wrought for flags, being sometimes slightly calcareous, and rather more sandy than the remainder of the subgroup. Quarries of these flagstones may be seen at the Garden House quarries near Aymestry, and in the hills east of Leintwardine, Mocktree Forest, &c., and at which places they are called "Pendle" by the workmen. This flaglike structure is due to fine laminæ of sandy matter separating the argillaceous layers. Occasionally these flagstones are separated from the overlying Aymestry limestone, by courses of a saponaceous clay (in many instances a complete fuller's-earth), of a yellowish white and grey colour, which is commonly known throughout Herefordshire and the adjacent counties under the name of "Walker's earth, or soap," and is sometimes used by the country people for cleansing purposes. Beds of this "Walker's[2] earth" are not in-

[1] In the Abberley hills and at other places, the rocks of this age and character are called *mudstones,* from their tendency to dissolve into mud. In the south-western parts of Salop, and adjoining parts of Montgomeryshire, they are termed *greenstones.* In a third district, they are known as *waterstones.* The most expressive of these provincial names is *mudstone.* In the sequel it will be shown that this term is generally applicable to the *Upper Silurian Rocks.*

[2] "*Walker Erde*", the German of fuller's earth, is evidently the origin of this provincial name. A Walk, or Walker's Mill, is still used occasionally instead of Fuller's Mill; hence "Walker's Earth," or "Walker's Soap."

frequent in other parts of the Upper Silurian Rocks, particularly in the Wenlock shale; and it will afterwards appear, that from their saponaceous qualities the surfaces of these beds have frequently aided the slipping of superincumbent masses of rock. (See Chapter 20.) The central and lower strata afford no good stone, and are often disposed in large sub-concretionary masses which frequently break into shivery fragments. The same strata often contain smaller concretions of black argillaceous limestone, varying in size from a few inches to three feet in diameter. These calcareous nodules are strikingly analogous to the cement stones or concretions of the lias, and other calcareo-argillaceous formations, and are frequently formed around an orthoceras, or some other organic body. Vertical or highly inclined joints occur throughout, the direction and inclination of which, like those alluded to in the upper Ludlow, vary with the changes in the strike of the strata. Nearly every quarry affords examples of these joints or backs. (See Chapter 20.)

The steep escarpments of any of the hills west of Ludlow expose the outcrop of the strata composing this subdivision. They dip under the Aymestry limestone and upper Ludlow Rock, and the same relations can be equally well studied in numerous localities at the back of Mocktree Forest, Shelderton Hill, descending to Clungunford[1], and in Leintwardine Hill upon the north side of the new road between the limekilns and the village below. In the inner or elevated portion of the Ludlow promontory, where the strata are much dislocated, (see subsequent chapter,) the detailed relations of the beds are well revealed, as in the deep comb called Mary Knoll Dingle. I may also particularly cite a section offered on the sides of a deeply worn lane which ascends from Elton to the high grounds of Evenhay, a prolongation of the ridge of Gatley Coppice. Here we see the Aymestry Limestone in the cap of the hill dipping south-south-east 15°, and underlaid by seams of Walker's Earth, and pendle or flaglike beds, with Orthocerata both large and small: argillaceous beds succeed, containing, here and there, concretions frequently of an oblate spheroidal form, of black or dark grey, compact, argillaceous limestone, which have been formed around organic remains (Orthoceratites, Trilobites[2], &c.). These are underlaid by clay and friable stone bands, with other fossils, including the chain coral, *Calamopora*, and beneath are lower hillocks, which are occupied by the underlying limestone of Wenlock. The Garden House quarries near Aymestry, expose excellent sections of a part of this subgroup, and the fine vertical cliffs on the left bank of the Lugg, between Aymestry and Deerfold Chase, are also composed of it.

[1] The geologist who may examine this tract cannot observe a more instructive section of the middle and lower members of the Ludlow formation than that which is laid open on the sides of the rugged road which descends Shelderton Hill. The hospitality of my kind friend, the Rev. J. Rocke, whose house, of Clungunford, is near the base of the hill, enabled me thoroughly to examine this section.

[2] In company with the Rev. T. T. Lewis, I counted forty fragments of the *Asaphus caudatus* in a single nodule.

The organic remains of the lower Ludlow, are upon the whole very different from those of the upper Ludlow Rock and Aymestry limestone; for although a few species of shells are common to the whole formation, this lower division is strongly marked by the presence of many peculiar remains, including *two new genera* which have not yet been observed in any overlying stratum; viz. the conchifer *Cardiola*, and the chambered shell *Phragmoceras*[1]. (*Cardiola interrupta*, Pl. 8. fig. 7, and *Phragmoceras nautileum*, Pl. 10. figs. 2 and 3.) These with the large Othoceras, *O. filosum*, Pl. 9. fig. 3; the singularly shaped Orthoceras, *O. pyriforme*, Pl. 8. figs. 19 and 20; the great Lituites, *L. giganteus*, Pl. 11. fig. 4, and the *Graptolites Ludensis*, Pl. 11. fig. 8, are peculiar and distinguishing fossils. The well-known Trilobites *Calymene Blumenbachii*, and *Asaphus caudatus*, Pl. 7. figs. 5 and 6, also abound, but these fossils are equally found in the Wenlock limestone. The small, serrated Graptolite of Linnæus, is very abundant in the ancient rocks of Sweden and Norway. The species above referred to being characteristic of the upper Silurian group, and common in the lower Ludlow rock, I have named it *G. Ludensis*. When first discovered in this country these bodies were supposed to be fucoids, but when examined by botanists they were discarded from the vegetable kingdom. Their true nature was afterwards pointed out to me by an eminent Danish naturalist, Dr. Beck, who after an attentive examination of several varieties found in rocks of the same age, proposes to describe them as zoophytes, bearing an analogy to some of the family of sea pens.

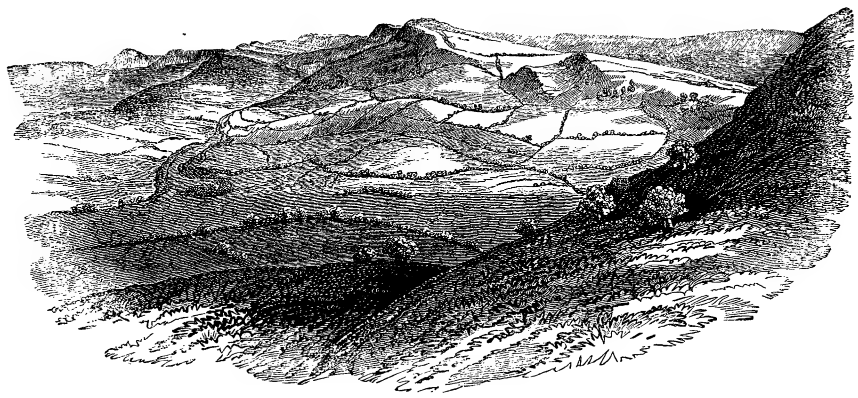
Here again the analogies and habits of this race of animals, as in the example of the zoophyte of the upper Ludlow rock, (p. 199,) accord completely with the nature of the surrounding sediment; for as the modern animals to which they are perhaps most nearly allied, live in mud and slimy sediment, so wherever these fossils occur, the rock is a finely levigated *mudstone*, which from its structure must have been tranquilly deposited.

In concluding the account of the Ludlow formation in this district, I may remark, that it is as void of simple minerals or veinstones as it is rich in organic remains. With the exception of crystals of carbonate of lime, which occur in rocks of nearly all ages, I am acquainted with no minerals beyond a very little iron pyrites and some thin strings of galena, one of which I observed in the bed of a brook near Larden in the upper Ludlow, another was detected in the same rock at a depth of sixty feet beneath Ludlow Castle. Besides the small nodules of iron pyrites noticed in the upper beds at Ludford, the same mineral is found occupying the place of the septa of the Orthoceratites which occur in the spheroidal nodules of the lower Ludlow rock.

*Probable thickness of the Ludlow Formation.*—The reasons which induced me to hesitate in estimating the thickness of the Old Red Sandstone, ought perhaps to prevent my attempting to calculate the exact dimensions of the Ludlow Rocks. We can, how-

[1] These new genera have been named by my friend Mr. Broderip, to whom on all questions connected with the comparison of fossil with recent genera I am under deep obligations.

ever, make a sufficiently close approximation; for no one can pass along the banks of the river Teme in the gorge at Downton, without perceiving that the upper Ludlow Rock alone, as interposed between the flaglike junction beds of the Old Red Sandstone near the Tin Mill, and the Aymestry limestone at Downton on the Rock, is many hundred feet thick; for in proceeding from east to west, the observer rapidly passes over successive strata, presenting themselves in separate ledges, and rising from beneath each other at gentle angles of inclination. The thickness of the Aymestry limestone is easily calculable, as the whole face of the rock is frequently exposed in one mass. Again, the escarpments of Mocktree Forest, Mary Knoll, &c., afford excellent data for measuring the dimensions of the lower Ludlow Rocks, as lying between the Aymestry and Wenlock limestones, and leave little doubt that this subdivision is quite as thick as the uppermost. We shall not therefore exaggerate in estimating the total thickness of the Ludlow formation at about 1500 feet.



*Wenlock Edge, as seen looking from S.W. to N.E.*

# CHAPTER XVII.

## UPPER SILURIAN ROCKS (*continued*).

### 2nd Formation "*Wenlock Limestone*," Equivalent "*Dudley Limestone*." (See Map and Pl. 31. figs. 2, 3, 4 and 5, and *e* and *f* of wood-cut, p. 196.)

THE Ludlow rocks occupying the chain of hills between the Onny and the Severn are succeeded on the north-west by a sharp rectilinear ridge, near twenty miles in length, called "Wenlock Edge." The strata of which this ridge consists rise at a slight angle from beneath the Lower Ludlow Rock; the inferior portion of the latter being soft, has been so denuded as to form a valley between the harder masses of Ludlow rock on the one side, and Wenlock limestone on the other. These relations are distinctly seen in the form of the country as represented in the vignette at the head of the chapter.

[a] The high ridge of upper Ludlow rock and Aymestry limestone. [b] The Wenlock Edge, the intervening valley having been excavated in the lower Ludlow shale. [c] The valley of the Wenlock shale.

The Wenlock limestone is in every respect identical with the well-known rock of Dudley, and contains the same organic remains. Here, however, it exhibits relations to the superior and inferior strata which do not exist at Dudley, and hence the name of "Wenlock" has been preferred[1].

[1] At Dudley, as will hereafter be shown, the limestone being abruptly protruded through the coal measures without the great connecting links of Ludlow rocks, Old Red Sandstone, and carboniferous limestone, no evidence whatever can there be obtained to prove its place in the geological Series; in Shropshire, on the contrary, a clear order of superposition exhibits all the passages and relations required, establishing the place of

This formation differs from the rocks above and below it, in containing thick masses of a crystalline and subcrystalline limestone, highly charged with corals and encrinites. In parts, indeed, the latter are so abundant, that the rock on a superficial glance might be mistaken for the mountain or carboniferous limestone; an examination, however, shows that the crinoidal remains, and the other fossils contained in the Wenlock limestone, are distinct from those of the Carboniferous System. Further, the strata are constantly arranged in concretionary masses, which are separated from each other by a vast predominance of argillaceous matter, an arrangement rarely, if ever, perceptible in the limestones of the carboniferous series.

The formation is naturally separable into *two divisions*, the upper calcareous, the lower highly argillaceous, with a few calcareous concretions. The first of these occupies the summit and slopes of the Wenlock Edge, the second appears in the escarpment and is spread out on the north-west in a longitudinal valley running parallel to the Edge. Let us first examine the upper or calcareous zone in the neighbourhood of Wenlock, where it is most expanded, and then follow it in its prolongation to the north-east and south-west to the banks of the Lugg.

### *Wenlock Limestone.* (*e.* of wood-cut p. 196. and Pl. 31. figs. 2, 3, 4, and 5.)

The chief calcareous strata of this formation are overlaid and underlaid by a number of small concretionary nodules of grey argillaceous limestone, running in layers and held together by a matrix of shale, which weathers to an ashen or yellowish green colour, whilst in some places the nodules unite and form irregularly thin-bedded, lenticular limestones. Both these varieties are exposed in beds above and below the principal masses of limestone in many quarries on the summit and south-eastern slopes of Wenlock Edge, and by the sides of the roads which traverse that ridge. In the Gleedon Hills, north of Wenlock, where the calcareous zone is most expanded, the strata undulate, and thick beds of impure concretionary limestone are exposed in the central and more solid masses of the rock.

To study the connexion of this upper subdivision of the Wenlock limestone with the lower Ludlow rock, we must follow the south-eastern face of the Wenlock Edge till it is flanked by the parallel chain of hills of the Ludlow rocks, as expressed in the opposite wood-cut, and we then perceive, that for many miles, the highest beds of the limestone rise up conformably, and for the most part at small angles of inclination, from beneath the lower shale of the overlying formation. At Presthope, courses of lenticular limestone, made up of irregularly flattened concretions and alternating with light-coloured shale, rise from beneath the lower Ludlow rocks, and pass down into a

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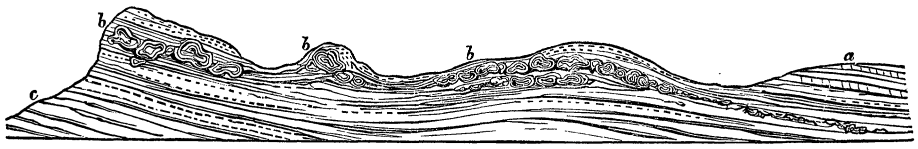
the Wenlock limestone to be at least 1500 feet below the base of the Old Red Sandstone. (See section, Pl. 31. fig. 2, 3, and 4.) Whilst, therefore, the type of the formation, like that of those above and below it, is derived from examples in Shropshire, any peculiarities in these rocks at Dudley and other places will be mentioned in separate and subsequent descriptions.

hard, blue, subcrystalline, thin-bedded, limestone. Some of the flattened nodules are concreted around nuclei of black chert.

Near Easthope the uppermost strata put on a different lithological aspect, becoming a marble of red and dull green colours, which has been a little worked for ornamental purposes. The red-coloured portion is composed of broken stems of encrinites and small corals; and the dull green colour is due to an intermixture of very argillaceous limestone. Beds of this description are exceptions to the prevalent concretionary characters of the upper portion of the limestone which are persistent over considerable areas. In those situations, however, where the formation is little developed, the thicker and central limestone having thinned out, it is only by such nodules and their associated fossils, that the place of this formation can be traced.

The central or chief calcareous masses are of very irregular thickness and dissimilar appearance. In certain quarries they consist of regular beds of argillaceous limestone, separated by way-boards of shale, which enters into all the crevices and depressions of the limestone; and occasionally is even more abundant than the calcareous matter. This *earthy* aspect, and the prevailing dingy ashen or greenish yellow to which the shale weathers, is one of the most striking external characters of this rock. In other quarries all traces of bedding are wanting, and the whole calcareous mass is made up of concretions, sometimes of immense size, surrounded by beds of shale and impure limestone. Examples, both of regular bedding and concretionary structure, are frequently exhibited in the same locality. When the limestone lies in regular beds it is generally more or less impure and mixed with argillaceous matter, but when arranged in concretions it is purer and more crystalline. These large concretions are called "Ball-stones" by the workmen, to distinguish them from the common beds, which they term "measures."

25.

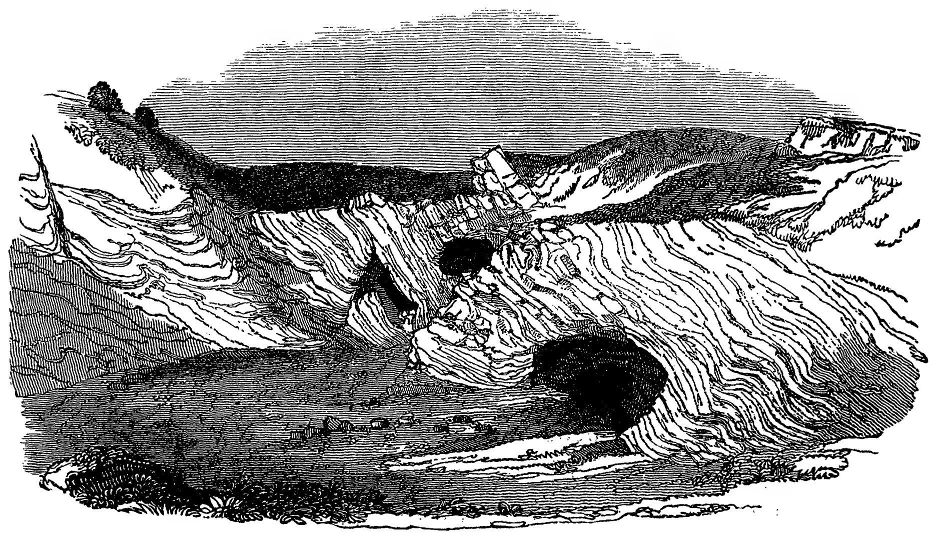



This wood-cut represents the order of the beds to the north of Wenlock. [a] Upper beds of lenticular limestone with nodules. [b] Chief mass of limestone with *ball-stones*. [c] Shale with small concretions.

The colour of the rock is usually dull grey, but the crystalline varieties are sometimes dark blue, and more rarely pink, the mass being freckled with veins and strings of white crystallized carbonate of lime. The same number of calcareous beds is not continuous over a large area. At Lincoln Hill, for example, where the limestone in the chief quarries is inclined at about 55° and 60°, we have the upper and lower suite of small concretionary beds, and the central system of purer thick-bedded limestone, having a thickness of about forty or fifty feet, but the best beds not exceeding in amount twenty to twenty-five feet. In these the workmen distinguish an upper and a lower limestone. These masses present the edges of distinct beds at the escarpment, but on descending into the subterranean quarries the lines of separation often disappear, and the whole of the calcareous matter unites at such points into large concretionary lumps or "Ball-

stones[1]." Where these concretions are prevalent, the strata undulate or are contorted as expressed in the preceding wood-cut. The succeeding wood-cut represents the old quarries at Lincoln Hill, where the limestone was extracted by being hauled up the inclined plane of the strata, and will convey some notion of these undulations or contortions. They have, I conceive, for the most part been formed during that process of solidification or crystallization which gave rise to the concretions of the limestone, and cannot be considered as resulting from the dislocations by which this tract has been agitated, for such concretions enter intimately into the structure of the Wenlock limestone[2].

26.



Old quarries at Lincoln Hill (Iron Bridge). The dark shades indicate the places from whence the concretions or *ball-stones* have been extracted. On the right hand b are the overlying coal grits (see p. 105.).

As we advance, from the gorge of the Severn to the south-west, the calcareous matter rapidly expands (see Map), particularly near Tickwood and Gleedon, where the limestone spreads over a width of upwards of a mile, occupying two promontories, extending between Wyke and Buildwas, in which much ball-stone is exposed. In one quarry recently opened (called the Yell), the small concretionary beds dip on the one side to the north, on the other to the south-east, and the centre of the hill consists of one massive ball-stone, which when I visited the spot, was laid bare to the depth of about *eighty feet!* the surface alone being covered with a few thin nodular beds[3].

[1] These are much preferred as a flux for the iron ore to the other impure and argillaceous beds.

[2] Mr. Prestwich assures me, that in the deepest recesses of these limestone galleries, the undulations, being at first gradual, increase with the depth, until at about eighty yards from the surface they present a series of very slightly curved arches about twenty yards long, separated by rapid, step-like descents of four to six yards each; but all these lines, however curved, are unbroken.

[3] The exact width of this mass of ball-stone had not been proved when I last visited these quarries, but it is doubtless very great, and must be of considerable value on account of its superior quality and accessible position.

Similar massive concretions, and of equal value, are exposed in the contiguous quarries of Bradeley; and the whole of the calcareous rocks around Gleedon also consist of crystalline concretions, of greater or lesser size, subordinate to thin argillo-calcareous beds. Some of the argillaceous matter is here of peculiar tenacity and of a white colour resembling pipeclay. Another remarkable ball-stone (not yet consumed by the lime-burners,) lies to the south-west of Wenlock, and is called "Ippikin's rock." It constitutes a boss, the summit of which is about four or five hundred feet above the valley occupied by the Wenlock shale. The rock itself has a vertical face of fifty or sixty feet, which is partially fissured, and presents an entrance into a small cavern[1]. It is a mass of crystalline limestone, the edge of which, as in the examples previously mentioned, is in abrupt contact with the ends of the surrounding strata.

The central and massive portion of the Wenlock formation, thins out rapidly to the south-west of Easthope, and although limestone is worked at various places along the crest of the south-western extremity of the edge, the largest nodules only are selected for use. Between the gorges of the Onny and the Teme, the line of this calcareous zone is marked by a few quarries, containing the small concretions only, the strata being much denuded in the low grounds of the valley extending by Clungunford to Leintwardine, but in the neighbourhood of the latter place the limestone re-appears through the surrounding shale near Clifton Ford Bridge. From this point it ranges distinctly around the interior of the Ludlow promontory, forming an inner and lower ridge, or rather a succession of bosses, the beds of which dip beneath the overlying escarpment. (Pl. 31. fig. 5.) It appears in like positions at the base of the escarpment of the Ludlow formation at various places near Aymestry, and is fully developed between Wigmore and Dickendale, and again on the banks of the Lugg near Kinsham.

In these situations it is made up of concretions, varying in diameter from two inches to two feet, which are abundantly charged with fossils, particularly corals. The nodules differ much in lithological structure, the smaller consisting solely of dull, grey, argillaceous limestone, whilst many of the larger are made up of white crystallized carbonate of lime.

*Wenlock Shale.*—Synonyms "*Dudley Shale.*" (*f.* of wood-cut, p. 196.)

The lower part of the Wenlock formation, as already stated, consists of a great development of dull, argillaceous shale, rarely if ever micaceous, and contains here and there, a few concretions of very impure, argillaceous, limestone. In colour, aspect, and want of cohesion these strata are nearly identical with those of the lower Ludlow rock, and they constitute the base of the Upper Silurian or "mudstone" rocks[2]. The

[1] This cavern, tradition says, was formerly inhabited by a person of the name of Ippikin. It has been recently examined at my request by my zealous young friend Mr. R. W. Evans, to ascertain if it contain the remains of cavern animals. The result will be communicated in the concluding chapters.

[2] The miners of the coal-field of Coal Brook Dale apply the name of "Die Earth" generally, to any beds of

superior strata of this shale are well exposed at the escarpment of Lincoln Hill, and they occupy the whole of Coal Brook Dale, properly so called, where they are cut through by the road which leads to Wellington, the coal-measures resting on their highly inclined strata. The same beds are equally well seen all along the escarpment of the Wenlock Edge, where they dip beneath and pass up into the lower nodular beds of the limestone. In some places the laminæ of deposit are indicated by large spheroidal forms. In the central portions the shale is very incoherent, and where it has been exposed to the atmosphere and not preserved by cappings of the harder limestone, it has been much denuded. This incoherent structure has invariably led to deep denudation, which in this tract is indicated by the longitudinal valley extending from the Severn to the Onny, in a line parallel to the Wenlock Edge, and between that ridge and the Caradoc Hills. Similar valleys are seen at the back of the escarpment of the Ludlow promontory, and indeed wherever this subformation is exposed.

Towards the base of this shale are sometimes courses of very impure limestone, which have a lenticular or rather brick-shaped form. Such beds occur in the slopes of the hills above Buildwas. Some of the spheroidal, argillo-calcareous concretions present when broken, an internal structure similar to the well-known "cone in cone" of the lias shale, the cones being frequently made up of dark-coloured crystalline carbonate of lime in an argillaceous paste[1]. Similar nodules, of the size and form of large loaves of bread, are sometimes found on the surface of the hills as we approach the Wrekin, and the same have been recently detected[2] near Cound, where they are included in the shale, which covers the Caradoc sandstone.

The shale is usually succeeded by sandy, calcareous bands, charged with peculiar fossils; but as in most cases they rise up in separate ledges reposing upon, and passing into the Caradoc sandstone, I have preferred to include them in that formation. As a general rule, therefore, we consider the upper Silurian rocks to have their natural base line, where the soft Wenlock shale ceasing, harder strata, for the most part sandy, but sometimes calcareous, begin to rise out from beneath them.

It is perhaps more difficult to calculate the entire thickness of the Wenlock formation than that of the Ludlow rocks, since many of its lower strata are much denuded and ill exposed. The limestone in the vicinity of Wenlock, including all the superior and inferior nodular strata, cannot have a less depth than two hundred feet: it possibly may in some parts amount to three hundred; and the thickness of the lower shale,

the Silurian System which they meet with below their coal measures. If this term had been strictly limited either to the shale above or to that below the Wenlock limestone, it might have been retained in geological nomenclature; but it cannot be used, because the carboniferous deposits of that tract rest on *various members* of the Silurian System, and hence the "Die Earth" beneath one shaft refers to the upper or lower Ludlow rock, beneath another to the Wenlock shale.

[1] In shale of this age in Montgomeryshire some of the nodules contain crystals of quartz mixed up with those of carbonate of lime, small flakes of anthracite, &c., and various organic remains. (See chapter 24.)

[2] On a farm of the Rev. Dr. Butler, now Bishop of Lichfield.

seeing the width over which it has extended, must exceed seven hundred feet; so that we shall not exaggerate in assuming a thickness of one thousand feet for the whole formation.

*Minerals.*—The simple minerals hitherto observed in the Wenlock limestone of Shropshire, consist of crystallized carbonate of lime in many forms, sulphate of barytes (rare), sulphurets of lead[1] and iron, peroxide of manganese in small quantities, crystals of copper pyrites (sulphurets), and bitumen. The copper pyrites and bitumen are found in veins associated with white calcareous spar lining the interior cavities, joints and fissures. When I first examined them at Lincoln Hill, I thought they might, like many other metallic veins, communicate downwards with fissures, connected with deeply-seated subterranean agency. Subsequent examination of some of these veins exposed in the quarries of Bradeley Field, near Wenlock, has, however, convinced me, that many of them are veins of segregation, which were formed when the calcareous matter was consolidating and assuming its present concretionary structure.

The limestone at Bradeley is crystalline, dark-coloured, and where not interfered with by *ball-stones* arranged in thick beds having a slight inclination. When deeply cut into, short veins are exposed, which are clearly seen to terminate both above and below. These are filled with white calcareous spar, penetrated by separate crystals of copper pyrites. Other larger and vertical rents have their walls lined with crystals of calcareous spar, the surfaces of which are coated over with black bitumen. Upon opening the cavities with the pickaxe, this bitumen exudes, and flows over the adjoining limestone. It was also stated by the workmen that large discharges of water accompanied the laying open of some of these cavities. Although such veins are particularly described at this locality, they are also found in other places where the limestone is thick and crystalline, and are invariably most abundant in the proximity of large *unstratified* concretionary masses. As they never occur in the upper or lower small nodular beds, and can in some instances be observed, fairly terminating at both ends in the limestone, it may be inferred that these veins are contemporaneous with the rock in which they occur, in other words, that they have been formed at the time when the purer calcareous matter separated from the argillaceous mass and formed the larger concretions.

*Organic Remains.*—The most striking zoological distinction of the deposit consists in the vast number of *Corals* with which it is charged. Among the most prevalent we may enumerate *Heliopora pyriformis* (de Blainville); *Catenipora escharoides* (Lamarck); *Stromatopora concentrica* (Goldfuss); *Favosites Gothlandica* (Lamarck); *Cyathophyllum turbinatum* (Goldfuss); *Limaria clathrata* (Steininger), &c. These corals, with many others belonging to this and the other formations of the Silurian System, are figured in Pl. 15 and 16., and will be described in a subsequent chapter by Mr. Lonsdale. The *Crinoidea*, which are also very abundant, appear in Pl. 17 and 18[2].

The conchifers and mollusks of the limestone are figured in Pl. 12. Of these the most common are *Euomphalus discors*, *E. rugosus*, and *E. funatus*, figs. 18, 19, and 20.; *Productus euglyphus* and *P. depressus*, figs. 1 and 2.; *Atrypa tenuistriata* and *A. aspera*,

[1] It is said that there were formerly lead mines in this limestone near Much Wenlock, but they have been disused for many years.

[2] The plates in which the *corals* and *crinoidea* appear not being completed while these pages are passing through the press, I am unable to refer my readers to the figures.

figs. 3 and 5.; *Terebratula imbricata* and *T. cuneata*, figs. 12 and 13.; *Nerita Haliotis*, f. 16, &c.

*Orthocerata* occur, but more sparingly than in the Ludlow formation. The *Orthoceras Brightii*, Pl. 12. f. 21. is a new but rare species.

*Trilobites* abound: *Asaphus caudatus* and *Calymene Blumenbachii* (Pl. 7. f. 6, 7 and 8.) which occur in the Lower Ludlow Rock, are the prevailing species. Others, however, are peculiar to the Wenlock formation, and are represented in Pl. 14, among which are *Calymene variolaris*, f. 1.; *C. macrophthalma*, f. 2.; *Asaphus Stokesii*, Nobis, f. 6.; and others including a species of the *Isotelus*, (Bar Trilobite) and an undescribed genus, which I have named *Acidaspis*, Pl. 14. f. 15. The shale or lower part of the formation is characterized by other species of shells, figured in Pl. 13., the most abundant of which are *Productus transversalis*, Wahlenberg and Dalm. f. 2.; *Spirifer cardiospermiformis*, Dalm. f. 8.; *S. trapezoidalis*, f. 14.; *Terebratula brevirostra*, f. 12$^{c}$.; *T. interplicata*, f. 12$^{b}$.; and *T. imbricata*, Pl. 12. f. 12.; *Asaphus longicaudatus*, Pl. 14. figs. 10 and 11.; and *Orthoceras attenuatum*, Pl. 13. f. 19.

I may here observe, that a few shells range through several of the Silurian deposits. One of these, the *Atrypa affinis*, Pl. 6. f. 5. (*Terebratula affinis* Min. Con.), is found in the Aymestry limestone and throughout the Wenlock formation, but it is most abundant in the former. Another species which is very plentiful, *Productus depressus* (var.) Pl. 12. f. 2., has the same range; indeed it may occasionally but very rarely be detected in the Caradoc sandstone, its chief habitat being the Wenlock limestone.

If, however, several individuals are common to two or more formations of the system, the greater number of species are *peculiar* to each succeeding stratum; and of the truth of this remark, I shall adduce strong additional evidence in the next chapter, when the contents of the Lower Silurian Rocks are explained.

The two formations of Ludlow and Wenlock possess so much of a common lithological aspect, and offer such intimate passages from one to the other in the distribution of the organic remains, that they form a very distinct natural subgroup, which I have termed *Upper Silurian*. The expediency of thus grouping them will be apparent, when these deposits are traced over a more extended area; for whenever the bands of limestone thin out, the masses having an uniform argillaceous or mudstone character, are so blended, particularly when they occur together in one mountain mass, (as for example in the Long Mountain, Salop, the adjacent parts of Montgomeryshire, and in Radnor Forest,) that the subdivisions, which are clear in this district, can no longer be detected.

I now proceed to point out the distinctions of other strata, which rising from beneath those above described are termed the *Lower Silurian Rocks*.

# CHAPTER XVIII.

## SILURIAN SYSTEM (*continued*).

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### Lower Silurian Rocks,

### *Caradoc Sandstone* and *Llandeilo Flags*.

3rd Formation *Caradoc Sandstone, g, h, i, k,* of wood-cut, p. 196. Sections, Pl. 31. figs. 3 and 4.

AS the overlying formations of Ludlow and Wenlock occupy separate parallel ridges, divided from each other by a longitudinal valley, excavated in the lower Ludlow rock; so the strata of this formation rise from a valley in the Wenlock shale and constitute a third ridge, parallel to those already described. The name has been selected, because the strata of which it is composed constitute a number of eminences, which abut against the remarkable chain of trap hills called the Caradoc, as represented in the opposite lithographic sketch. *a*. The Ludlow rocks. *b*. The Wenlock limestone. *c*. The Caradoc sandstone rising up in the hills described, and resting upon the trap rocks ($r'$) of the Caer Caradoc and ($r$) Lawley. The Wrekin appears in the distance ($r''$). The remote country is occupied by New Red Sandstone and coal measures. The villages of Kenley, Church Preen, Acton Burnell, Hope Bowdler, and Acton Scott are built upon these rocks, and their various beds are traversed, in passing from the valley on the west of Wenlock edge to the flanks of the Caradoc chain. Instructive sections may also be observed in crossing the south-western extension of these hills[1], at several points between Acton Scott and Cheney Longville. The clearest of these sections is that exposed upon the banks of the Onny, between Wistanstow on the south-east, and Horderly on the north-west. Where not much dislocated, the uppermost strata dip to the south-east at angles of eight to ten degrees, the inclination of the lower strata increasing to thirty-five, forty, sixty degrees, and even to verticality, as they approach and come into contact with the trap rocks, or lie upon the anticlinal lines marked by the prolongation of the Caradoc ridge.

Unlike the mudstones of the upper Silurian rocks, this formation is composed essentially of sandstones of different colours, with an occasional subordinate course of calcareous matter. To convey a correct notion of the nature and succession of the strata,

[1] These hills are from 500 to 800 feet high.


T. Webster del.

VIEW FROM THE SIDE OF CAER CARADOC.

looking North.

Day & Haghe Zinc.

I will first describe a natural section on the banks of the river Onny, commencing near Wistanstow, where the strata rise from beneath the Wenlock shale, and terminating with the lowest beds of the formation at Horderly Gate. Although a clear order of succession in the upper masses is here exhibited, this section does not fully develop all the subordinate parts of this formation; and therefore each subdivision displayed on the banks of the river, will afterwards be traced on its strike, to show the great expansion of some beds, in their course to the north-east, or in those hills which form the south-eastern flank of the Caer Caradoc.

*Transverse Section on the Banks of the Onny.*—1. Thinly laminated, sandy shale, only slightly micaceous in the upper part, but more so in the inferior, and weathering to a yellow colour. It contains thin courses (one to four inches) of sandstone charged with fragments of shells, and streaked with thin layers of whitish pipeclay, and towards the lower part many thin bands of impure sandy *limestone*. The latter may be detected in the bed of the Onny, and when first quarried, the layers, four or five inches thick, are of a dull, dark grey, or bluish colour, and break into lozenge shapes.

Some of the calcareous bands in this subdivision expand in their progress to the north-east. For example, at the Hollies, to the east of Hope Bowdler, there are several courses eight to ten inches thick, which have been extracted and burnt for lime. (*g* of wood-cut, p. 196.)

The fossils characteristic of the upper zone of the Caradoc formation are figured in Pl. 19. Among them are ***Productus sericeus***, f. 1.; ***Bellerophon bilobatus*** and ***B. acutus***, f. 13 and 14.; ***Littorina striatella***, f. 12.; ***Orthis alternata***, ***O. callactis***, (*b*) Dalman, figs. 5, 6, and ***O. canalis***, Pl. 20. f. 8.; ***Pentamerus lævis***, and ***P. oblongus***, f. 9 and 10. We here lose all traces of the trilobites common to the Upper Silurian rocks (Pl. 7.), and in place of them we meet with other forms, including the ***Trinucleus***[1], Llhwydd., a genus never observed in the Upper, yet abounding in the Lower Silurian rocks, particularly ***T. Caractaci***, Nob., Pl. 23. f. 1., and an undescribed large species of ***Asaphus***, which I have named ***A. Powisii***. (See Pl. 23. f. 9 and 10.)

Impure limestone is also very generally found in the upper beds of the Caradoc sandstones, in distant parts of Herefordshire, as on the western flank of the Malvern Hills, where besides some of the above-mentioned fossils, it contains some Orthoceratites and many fragments of Crinoidea. It forms also the outer coat of the central dome of the Caradoc sandstone in the valley of elevation at Woolhope, hereafter to be described.

These upper beds, on the Onny, dip 20° S.E. beneath the Wenlock shale, containing the *Asaphus longicaudatus*, (Pl. 14. f. 11, 12, 13, 14.) whilst the lower strata graduate downwards into sandy flagstones. They are placed at the top of the Caradoc formation, not only by their stratigraphical position, but also by their mineral structure and

[1] Fragments and imperfect specimens only of these Trilobites having been published, I was about to name this genus *Tretaspis* from τρητὴ ἀσπὶς, a shield perforated or deeply sculptured on its margin, for such is the leading generic distinction; when considering that an unquestionable species of this genus was long ago figured by Llhwydd (Lythophyl. Brit. Ichnogr. 1699, p. 97. t. 23,) as *Trinucleus fimbriatus*, I have in obedience to the practice of the best zoologists retained the original name. The American author Green, to whose work I shall have occasion to refer in the sequel, (see chapters on organic remains,) has recently proposed that this genus be called *Cryptolithus*, but this term does not explain any peculiarity of organization, and offers no inducement to relinquish the name of the old English naturalist.

organic remains, in both of which they are very distinct from the overlying deposit of Wenlock.

II. Slightly micaceous, very fine-grained, flaglike sandstone, of gosling green, and dingy olive green colours, in beds from one to six inches thick. It is very finely laminated, and so void of argillaceous matter, that even way-boards can scarcely be detected. These beds include calcareous courses of bluish colours, as seen in a low cliff on the right bank of the river, and in the deep lanes at and above the village of Cheney Longville. In the lower part, the strata become rather thicker, calcareous and shelly matter appearing at intervals, with rarely a thin partition of clay.

One of the most marked features of the beds of flag and tilestone is, that on fracturing the rock, the fossils frequently stand out in the form of neat casts, the surfaces covered with the brown and yellow hydrate of iron, thus presenting themselves in marked relief to the dingy green or red colours of the matrix.

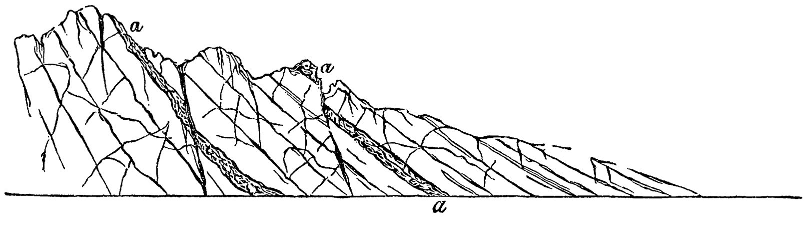
The prevailing fossils are the *Avicula orbicularis*, Pl. 15. f. 2.; *Orthis Actonia*, Pl. 20. f. 16.; *O. grandis*, Pl. 20. f. 12 and 13.; with an occasional Trilobite, such as *Trinucleus Caractaci*, *T. fimbriatus*, &c.

This group of flaglike strata at Cheney Longville and on the banks of the Onny, cannot be estimated at less than three or four hundred feet in thickness (*h* of wood-cut). They dip to the south-east at about 25°, and may be observed on the bank of the stream as well as on the sides of the roads which traverse the strata, particularly in ascending from Cheney Longville to the common, where they have been long and largely quarried as tilestones. Similar beds may be traced, in the same position, on the south-eastern face of the hill of Woolston, at Acton Scott, at Soudley near Cardington, &c. On the whole the aspect of these beds is peculiar, and if the fossils were excluded, some of them might almost be mistaken for sandy *clay stones* of trappean origin: and it will be hereafter shown that beds of this nature in the immediate flanks of Caer Caradoc, pass into what I have termed "Volcanic Grits." (see p. 229.)

III. Thick-bedded, finely grained, siliceous sandstones, sometimes of reddish colours, but for the most part of a dingy olive green, and striped in the direction of the laminæ with bands of dark red or purple. Some of the beds are very thick and fit for the largest troughs; others are wrought into flags six inches thick. This stone has a conchoidal fracture, and is usually fissured by a number of vertical and oblique joints of irregular forms, having the interstices filled with clay, generally of a red colour, the same matter forming the way-boards. It contains some irregular courses of very impure limestone, made up of shells, chiefly the *Orthis testudinaria* Dalm., Pl. 20. fig. 9., and *Productus sericeus*, Pl. 19. fig. 1.

In the south-western prolongation of this system, similar beds are cut through by the old road from Ludlow to Bishop's Castle, called the Long Lane, where they are well exposed in deep quarries, and where, as at Soudley, near Hope Bowdler, they are worked for troughs, tombstones and building purposes, presenting the same peculiarities of structure, fossils, fissures, colour, &c., which have been before remarked. The lower beds at the Long Lane quarry are considerably inclined and disturbed in the manner represented in this wood-cut.

27.



At Soudley the sandstone is overlaid by the same shelly flagstones and impure limestones described in the section of the Onny, and is cut into to a depth of thirty or forty feet. The prevailing colour of the rock is red, with some beds of dull green, striped with darker red, and there are also courses of shale. Among the fossils are *Avicula obliqua*, Pl. 19. f. 4.; *Orbicula granulata*, Pl. 19. f. 5.; *Orthis Pecten*, Pl. 20. f. 9., with other shells common to the formation.

The surfaces of the beds are frequently marked by casts of awl-shaped bodies, the *Tentaculites* of Schlotheim, and the ends of the stems of *Crinoidea*. The latter fossils are eminently characteristic of several subdivisions of the Caradoc sandstone, particularly the *Tentaculites annulatus*, (Pl. 19. f. 15.). The same thick-bedded red rock with similar relations, is seen in quarries at Wilson, near Cardington.

iv. Sandy and pebbly grits, of reddish brown and yellowish colours, in thick and thin beds; the latter frequently containing casts of shells and portions of trilobites. On the left bank of the Onny, quartzose grits rise into the high grounds of Woolston and Horderly. Towards their base they become *so calcareous* as to be partially burnt for lime, and are exhibited on both banks of the Onny, at angles of seventy and eighty degrees, still inclined to the east and south-east. This calcareous grit is here about twenty-five feet thick, and is flanked by thin courses of shale, of mottled bluish grey colour.

The calcareous grit (*i* of wood-cut) contains the large *Orthis anomala*, Pl. 21. f. 10. (*Terebratula anomala*, Schloth.,) the *Pentamerus oblongus*, and the plumose coral *Calamopora fibrosa*, (Goldfuss). The same calcareous rock is again exposed to the north-east in the escarpment called the Broken Stones, underlying the sandy and pebbly grits. This section of gritty and pebbly beds can be traced at various intermediate points, to the north-east, between the Caradoc ridge and the villages of Cardington, Enchmarsh, and Chatwall, always underlying the purple and green sandstone. The highly sculptured bucklers of the genus *Trinucleus*, and also the beautifully ornamented tails of the trilobite *Entomostracites punctatus* (Wahlenberg), Pl. 23. f. 8. are not uncommon.

To the south-west of the Onny, these quartzose grits are interposed between the Long Lane quarries and Wartle-knoll; and ranging through the red hills of Aston, they appear for the last time in this district in the low promontory of Corton. At the latter place, the thick beds extracted as building-stones are chiefly of grey colours, but contain small fragments of pink jasper, and occasionally patches of green earth. In the thinner and overlying strata, casts of fossils are numerous, chiefly the *Orthis flabellulum*, Pl. 21. f. 8.; *O. Vespertilio*, Pl. 20. f. 11.; and *Terebratula unguis*, Pl. 21. f. 13. To the south-west of Corton, these porous and coarse grits, dipping on all sides beneath the argillaceous shale of the overlying formation, become, from their low position, filtering-stones, through which the wet descends, and then naturally decomposing, form an excellent gravel, unlike any stratum in the surrounding country[1].

v. Deep reddish purple sandstone, with streaks of dirty yellowish green, in beds from six inches to two and three feet.

These strata (*k* of wood-cut) are seen for the distance of two hundred paces on the left bank of the Onny to the west of the calcareous grit; and though these beds are

[1] The Rev. J. Rocke of Clungunford first pointed out to me this peculiar gravel.

here nearly vertical, and much distorted, there can be no doubt they underlie all the system above mentioned. Indeed, they are dissimilar in mineral composition to any of the overlying strata. From their red colour and the great admixture of clay and marl, which are associated with them, they might be lithologically identified with many beds of the Old or even of the New Red Sandstone, described in previous chapters. The section of the Onny does not clearly expose any lower beds in the series. The black brittle schist which succeeds, may possibly represent a portion of the Llandeilo flags, but apparently it contains no fossils. In this section, indeed, the Caradoc formation has its natural termination at Horderly-gate, for, as will hereafter be shown, this point being upon a line of trappean eruption, the strata are thrown off in an anticlinal form.

At the north-eastern end of the Caradoc and Lawley hills, the lower sandstones are much more fully developed than on the banks of the Onny. In a traverse from the hills of Church Preen, by Broome to Chatwall, we pass over the overlying strata, consisting of impure limestone, shelly flagstone, sandstone, and grits before mentioned, the inclination of the lower strata increasing as they approach the ridge of the trap, (see coloured view, facing p. 216, and Pl. 31. f. 4.). Thence travelling across a valley of denudation, which has been excavated in shale, we find a bold and sharp ridge of sandstone and grit, rising up into the Hoar Edge, and running parallel to the general strike of all the other strata, and to the Caradoc and Lawley; the angles of inclination of the beds having increased to sixty degrees. In the quarries the descending section consists of—

1. Grits and coarse sandstone, of brown and yellow colours.
2. Pure, white, fine-grained sandstone, the interstices between the grains being occasionally filled up with decomposed felspar, which, when abundant, gives in certain states of decomposition a yellowish and freckled aspect to the rocks.
3. Yellowish sandstone, with ferruginous streaks and stripes of blue, red, and yellow colours.
4. Deep red sandstone.
5. Whitish gritty sandstone. (*Dip 55° to 60° S.E.*)

The beds in all are about fifty feet thick. Troughs of very large size are extracted, and much of the stone is of very superior quality, being quite equal to many esteemed building-stones in the carboniferous system, from which indeed it is undistinguishable in hand specimens. These quarries expose but a small portion of the strata of which the Hoar Edge is composed, and the inferior strata lying between this ridge and the Lawley have been much denuded, leaving a deep, narrow, intermediate valley; but upon their strike to the south-west, between Enchmarsh and the little Caradoc, the sandstone and grits expand considerably, and contain many of the fossils to which we have alluded. In the next chapter it will be shown that where the sandstones and grits have been cut through by the eruptive trap rocks of Caer Caradoc, they have been thrown into vertical, broken, and fantastic forms, and in many places altered into quartz rock. The zone of bright yellow colour on the eastern edge of the Caradoc and Lawley Hills, as represented in the coloured view, p. 216., indicates the position of the

quartz rock. The same phenomena occur on the flanks of the Wrekin and other places, where trap rocks protrude through similar sandstones. (Pl. 29. f. 11.) In the undulating and wooded hills of Acton Burnell and Cound, this Caradoc sandstone is repeated by reversed dips of the strata; and also on the north-western side of the anticlinal line of the Caradoc, so that the observer will find white sandstone at Cound and Stevens' Castle, and red sandstone and shelly beds in Acton Burnell, &c. On the eastern slopes of the latter hills, some of these shelly beds, containing principally *Productus complanatus*, Pl. 20. f. 6.; *Orthis vespertilio*, Pl. 20. f. 11, &c.; have been quarried and polished for marble ornaments[1].

Besides the strata already mentioned, there are other rocks which constitute prominent members of the formation for short distances only. Thus the villages of Kenley and Church Preen, stand upon coarse grits, in parts almost quartzose conglomerates, which for three or four miles, form one of the uppermost strata of the Caradoc sandstone; for they rise at low angles from beneath the Wenlock shale[2]. This coarse rock is used as a building-stone, and may be seen in the houses of the village of Harley below Wenlock Edge, where those who identify rocks by *mineral* characters would have some difficulty in distinguishing it from the millstone grit of the coal-measures. At Kenley, the small white quartz pebbles of the rock are held together in a strong ferruginous cement; and the beds have an united thickness of twelve or fourteen feet, becoming in some places a fine, hard, chocolate-coloured, coarse sandstone. At Church Preen it is largely quarried, and is a ferruginous, gritty sandstone, in parts a conglomerate, the dip being ten degrees to the south-east. To the south-west of Church Preen, this stratum thins out, and is no longer visible. In the central and lower beds of the series, exposed in the escarpment at Chatwall, there are thick- and thin-bedded yellowish sandstone, calcareous flagstone, conglomerate grit, and purple and green micaceous sandy shale. The conglomerate at this place is lithologically distinct from that of Church Preen, and contains pebbles of quartz, in sizes varying from peas to almonds; and in some of the beds there is much disseminated green earth and other disintegrated materials of trap rocks, giving a varied appearance to the strata. These accumulations, it will be observed, are on the flanks of the trappæan chain of the Caradoc. Similar conglomerate beds are laid open at Enchmarsh, overlying chocolate-coloured sandstone and dipping 50° south-east. This formation has been considerably denuded in the valley of the Severn, but it reappears in the north-easterly prolongation of the strata, on the south-eastern flanks of the Wrekin, where it dips rapidly on one side beneath the carboniferous limestone and coal-measures (see Chap. 7. p. 109.); and on the other is both recumbent on and perforated by trap rocks. Some of the sandstones on the sides of the Wrekin and Ercal Hills, are extremely shattered, and altera-

[1] They have been used in the mansion of the proprietor, Sir Edward Smith, Bart.

[2] At Woolhope, also, it will be seen that coarse quartzose grits, almost conglomerates, rise out at once from beneath upper courses of bastard limestone, like those of the Hollies, &c.

tions are produced in them, similar to those to which I have alluded as occurring on the sides of the trap rocks of Caer Caradoc. These transmutations will be described in the next chapter. The Caradoc Sandstone is again exhibited in mountainous masses, both in the south-western tracts of Shropshire, and largely in Montgomeryshire and the adjacent parts of Denbighshire, particularly on the left bank of the river Ffyrnwy near Meifod; but the description of these masses is reserved, until I have explained the linear outbursts of volcanic rocks, and the various anticlinal lines by which the formations of the Silurian System have been broken up and separated. In the meantime we have sufficiently described the great and complex formation of the Caradoc sandstone in the district where it emerges conformably from beneath the formations of Ludlow and Wenlock; and the descriptions of beds of similar age in other tracts will be less diffuse. It may be remarked, that although so low in the series of deposits, the formation is made up of beds of red, green, and purple sandstones, some of which it is difficult, upon first inspection, to distinguish from strata of the Old, or even of the New Red Sandstone. Its best and clearest distinctions consist, however, in its order of infraposition to the upper Silurian rocks, and its organic remains, nearly all of which are dissimilar from the fossils of the formations which immediately overlie it.

*Mines and Minerals.*—Malachite, or the green carbonate of copper, occurs in thin films and nests, and is occasionally slightly diffused through the sandstone of Longlane, Soudley, &c. Copper ores were formerly worked in these beds near Cardington. These veins lie near the contact of the deposits, with the trap rock of the Caradoc ridge, and will be alluded to in the ensuing chapter. Thin strings of galena, with some associated crystals of blende, have been also found in the south-western termination of this system at Corston Heath, where the beds are also much dislocated and altered, but none of these trials ended in profitable mining adventures. It will, however, be seen that in other districts where trap rocks abound, beds of this age are penetrated by rich and productive lead veins.

"*Llandeilo Flags*,"—4th Formation.—*Base of Silurian System.* (*l* of woodcut, p. 196.)

The Llandeilo flags are not seen in that district of Shropshire which has been selected as affording the clearest and fullest types of the superior formations. They have, therefore, been named after the town of Llandeilo in Caermarthenshire, where they are largely developed. They consist of hard, dark-coloured flags, sometimes slightly micaceous, frequently calcareous, with veins of white crystallized carbonate of lime, and are specially distinguished by containing the large trilobites, *Asaphus Buchii* (Brongn.), Pl. 25. f. 2.; and *A. tyrannus* (Nob.), Pl. 24. and Pl. 25. f. 1. Their relations and peculiarities at Llandeilo will be described in the chapter on Caermarthenshire; it being sufficient now to state, that these flags there occupy various ridges, pass under sandstones, the equivalents of those of the Caradoc, and are seen in some situa-

tions to graduate downwards into the older strata of the Cambrian System, as represented in the woodcut, p. 196, (see also Pl. 34. figs. 3. and 8.). In the immediate neighbourhood of Ludlow and Wenlock, on the contrary, there is a great break along the base of the Caradoc sandstones, occasioned by the outburst of trap which will be soon described (Pl. 31. figs. 3. and 4.), so that the exact place of the Llandeilo formation cannot be there established. Without, however, quitting Shropshire and the adjacent tracts of Montgomeryshire, we can prove the flags to be of older date than the sandstones, because the latter, as exhibited on the slopes of Caer Caradoc, contain no strata lithologically resembling these flags, whilst in several situations on the north-western side of the Longmynd and Stiper stones, true dark-coloured Llandeilo flags, containing the characteristic trilobites, rise from beneath sandstone charged with many well known Caradoc fossils (Pl. 32. figs. 1. and 2.). That these Llandeilo flags dip beneath the Caradoc formation, is also proved by continuing a transverse section to the north-west of the Vale of Meifod (Pl. 32. fig. 9.) ; when, after passing over many ridges composed of Caradoc sandstone with fossils, we meet with dark calcareous flags charged with the *Asaphus Buchii*, &c., emerging from beneath the sandstones, and reposing upon the slaty rocks of the Berwyn mountains. (See the end of Chap. 24.) It is from these combined evidences, drawn from different localities, that the Llandeilo flags are proved to be of higher antiquity than the Caradoc sandstone, properly so called. Some geologists, seeing the vast thickness of the Caradoc sandstone, and the comparatively small dimensions of the Llandeilo flags, with the occasional recurrence of sandy beds beneath them, might prefer to comprehend under the former name both deposits. Taken in this sense the Llandeilo could be considered only a subdivision of the Caradoc formation. After mature consideration, however, and the examination of numberless sections, I have preferred retaining the Caradoc sandstones and Llandeilo flags as separate formations, terming the whole "Lower Silurian Rocks", and premising, that where certain calcareous bands and peculiar beds of fossils disappear, it is not practicable to maintain the division of the group into distinct formations. On the contrary, however, where fully expanded, as in Caermarthenshire and Pembrokeshire, these flags are often of much larger dimensions than the Caradoc sandstone : besides which the flags are so strongly marked by lithological characters, and the presence of distinct trilobites, that there is no difficulty in distinguishing them from the overlying sandstone.

In the vicinity of trap rocks, these flags, like the Caradoc sandstone, frequently contain mineral veins, chiefly of lead. In the Shelve and Cornden district, such ores are largely worked. On the flanks of the Berwyns in Montgomeryshire, and near Llandrindod in Radnorshire, they are small and unproductive. The productive ores of the Cornden and Shelve district will be described at length in the twenty-second chapter.

It is scarcely possible to estimate the thickness of these flags, nor is it necessary to do so. In Caermarthenshire, where the overlying formations are attenuated, they are,

as already stated, much expanded, and of considerable dimensions; and in Pembrokeshire, where they contain large masses of good limestone, they are of still greater breadth.

The organic remains are described in subsequent chapters. Most of the conchifers and mollusks found in these flags, occur also in the Caradoc sandstone. Certain trilobites, however, as above stated (*Asaphus Buchii* and *A. tyrannus*), are peculiar to this deposit, while other crustaceans of the genus *Trinucleus*, though exclusively characteristic of the Lower Silurian group, are common to both the lower formations.

Enough has already been stated to demonstrate, that as we descend into older strata, we meet with fresh types of animals: for although two or three species of shells of the Upper Silurian Rocks may be detected in the Lower Silurian, the *mass of organic remains in each group is very distinct*. The least practised observer may convince himself of the truth of this assertion, by comparing the figures represented in Plates 4 to 18, with those from 19 to 27 inclusive. In the former are included all the known fossils of the Upper Silurian, in the latter those of the Lower Silurian rocks. The fossiliferous distinction is indeed most strikingly maintained by the crustaceans, for as yet I am acquainted with no example in which a trilobite of one group has been detected in the other.


VIEW OF THE CARADOC HILLS, &c. FROM THE LONGMYND.

T. Webster del.t

Day & Haghe Lith.rs

# CHAPTER XIX.

## SILURIAN SYSTEM (*continued*).

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*Trap and altered Rocks of the Caradoc, Wrekin, &c.—Periods of Volcanic Eruption.—Dislocations and Outliers of Silurian Rocks.*

WE now proceed to consider the structure of the principal ridges of rocks of volcanic origin which appear in connection with the Lower Silurian Rocks in the country above described.

### *Caer Caradoc.*

The bold, narrow, and sharp ridge called the Caradoc is about seven and a half miles in length, tapering at the extremities, and never exceeding half a mile in breadth. The culminating point, or the Caer Caradoc, is 1200 feet above the sea, but the Ragleath or south-western termination does not exceed 1000 feet, and the Lawley or north-eastern 900 feet. Several of the intervening and smaller hills do not attain to such elevations. The ridge has a large buttress on its south-western flank, constituting the hills of Hope Bowdler and Cardington, which nearly rival in height the Caer Caradoc and are upwards of a mile in breadth.

The Caradoc Hills are chiefly composed of different varieties of *un*bedded or amorphous trap, the most characteristic specimens of which may be collected from the rugged bosses which protrude through the verdant slopes or rise to their summits, contributing to embellish their picturesque forms. (See the opposite sketch.) The rock frequently appears through the grass in long dykes, from ten to fifteen feet wide, which meeting in the culminating points of the hills give them a radiated appearance. Their structure is also to be studied in the transverse combs and hollows which separate one hill from another, in broken chasms upon their sides and in the beds of small watercourses which descend from them. The predominant unstratified rock is pink, hard, compact, felspar, breaking into irregular rhombic forms, a clear fresh fracture being obtained with difficulty. From this compact felspar there are passages into, and alternations with, so many varieties of syenite and greenstone, that it is impossible to separate

the one from the other. These different substances will be first described, and it will afterwards be shown, that amorphous masses made up of these materials have dislocated and highly altered the adjacent strata.

In the *Lawley* we find compact felspar rock passing into hornstone; felspar rock occasionally coloured green by chlorite; fine-grained syenite with and without olivine; amygdaloid having a base of purple felspar and hornblende, more or less intermixed with green earth, which from a simple rock passes into one in which the amygdaloidal structure prevails, the globular concretions consisting chiefly of glassy, greenish yellow, radiated actinolite, with some green earth, calc spar, and quartz.

This is the beautiful amygdaloid first described in Dr. Townson's "Tracts," and again mentioned by Mr. A. Aikin, Geol. Trans., 1st series, vol. i. p. 210. It was supposed to be peculiar to the north-western face of Caer Caradoc, but I have discovered it near the summit of the Lawley, in the Little Caradoc, and in Hope Bowdler Hill, &c. It may therefore be considered common to the range.

*Little Caradoc.*—Felspar rocks as in the Lawley; greenstone containing numerous crystals of white glassy felspar.

*Caer Caradoc.*—Compact felspar rock is in great abundance as in all the other hills; the most beautiful variety is cellular, the cavities varying in size from that of a small almond to a pin's head and all compressed.

These cells are lined with minute hexahedral prisms of quartz mixed with a greenish yellow, earthy matter, perhaps decomposed actinolite? This rock is penetrated by veins of quartz, flesh-red felspar and chalcedony, the latter of which fills all the cells of the adjacent rock (Aikin, p. 210). The Caer Caradoc also contains greenstones of several varieties, some of which are so fine-grained as almost to pass into basalt[1]. In *Haslar, Helmeth,* and *Ragleth* Hills, there are ill-defined greenstones, with felspar rock, claystone, &c.

*Hope Bowdler.*—Rocks of compact felspar near Woodgate Bowdler, coloured green by chlorite, the red felspar giving to them a mottled aspect. Parts of these rocks have a bedded appearance and a steatitic feel, and in some specimens plates of green earth alternate with laminæ of pink felspar.

In a gorge leading from Woodgate Bowdler to the Battle stones, the compact felspar is slightly porphyritic; another rock has a base of compact felspar and hornblende, with crystals of common felspar, thus indicating a passage into greenstone.

At the knotty points called the "Battle stones," which stand out on the western face of the Bowdler Hills opposite to Caer Caradoc, is seen a trap conglomerate including concretions of compact felspar, quartz, green earth, and minute scales of talc. Another variety at this wild and rugged spot, is a compound of small grains of quartz, in a base of compact felspar, tinged green by green earth.

This range of hills presents many well developed cases of changes in the structure of the adjacent sandstone, which have been effected by the trap.

For instance, we may follow the strata of the Caradoc sandstone, full of fossils, as they range by Chatwall and Enchmarch to Cardington, where they are cut in upon by the great mass of unstratified trap rocks, of Cardington and Hope Bowdler Hills

[1] In a most instructive collection of rocks from these hills made by the Rev. J. Yates some specimens are considered by him to be true basalt. (Museum of the Liverpool Institution.)

above described; and in place of beds of sandstone we there find them suddenly changed into a serrated pile of arid quartz rock of exceedingly picturesque forms, (the Sharp stones) rising to about seven hundred feet above the sea, and in which nearly all traces of bedding have been destroyed, the lines of stratification, which can be defined, being inclined at very high angles.

Again, if we track the older strata of the same formation upon their strike from the quarries of Frodesley and the Hoar Edge, to their contact with the trap of the Little and Great Caradoc, we meet with precisely the same phenomena, the evidence in this case being still more decisive. In the sandstones, at a certain distance from the trap, the mechanical form of the grains of quartz is very evident, and they are associated with much disseminated felspar. On the north-east side of Little Caradoc, or rather between that hill and the Lawley, the sandstone is thrown up in vertical beds striking nearly east and west, and is in a state approaching to quartz rock, being much indurated and in parts cellular, the cells frequently containing green earth and malachite; whilst on the absolute face and summit of the trap of Little Caradoc, as well as on the eastern face of the Lawley, the sandstone is only to be detected in the state of true quartz rock, in most instances the trace of bedding being entirely destroyed, and the rock resting as a thin cover or in detached fragments upon the trap. Similar masses of quartz rock adhere to the sides of these trap hills at the Battle Stones.

In one of the quartzose veins, proceeding from the Caer Caradoc, the Rev. J. Yates discovered crystallized galena, an interesting fact as connected with the theory of metallic veins, respecting which much additional information will be communicated in the twenty-second chapter, upon the volcanized mining tracts west of the Stiper Stones. The environs of the Caradoc alone would, however, be almost sufficient to lead us to believe that veins have frequently been filled or enriched with metallic substances during the evolution of igneous matter through sedimentary deposits, for the altered sandstones around the edges of the protruding masses of trap near Hope Bowdler, are traversed to some extent by veins of copper ore, some of which have been slightly worked at former periods[1].

Without quitting the county of Salop, and restricting our observations to the vicinity of the Wrekin and the Caradoc, we are thus furnished with numerous examples of great mineral changes which have taken place in these sandstones, when they are in contact with, or in the proximity of certain rocks of intrusive characters and igneous origin, and the inference appears to be irresistible, that the sandstone has undergone the change of composition through the action of heat, evolved during the eruption of the volcanic matter.

[1] Mr. Yates noticed vertical strata of quartz rock passing into sandstone with a vein of trap passing through them. He also observed malachite in the quartz rock and in those peculiar sandstones which I have termed volcanic grit, and also in the ordinary sandstones of Long Lane quarry. Geol. Trans. vol. 2, p. 246. This mineral (green carbonate of copper) is largely disseminated in the adjoining districts to the westward. (See chapter 22.)

The highly inclined and dislocated position of the beds of sandstone, wherever they approach to these hills, is of itself sufficient geological evidence that the trap has been forced up through these sediments, and where we find these movements accompanied by such remarkable changes of lithological structure we can no longer doubt of their origin[1].

Such is the composition of the trap and altered rocks of the Caradoc Ridge. Having remarked that the Caradoc sandstone, extending through Horderley to Aston and Corton, terminated in a narrow anticlinal on the line of Caer Caradoc, I was induced to search for trap rocks in that direction. The first clear exhibition of them I discovered is at Wartle Knoll, eight miles south-west of Ragleth, the south-western end of the Caradoc. (see Map.) This conical hill is similar to many parts of the Caradoc, consisting chiefly of compact felspar with passages into coarse and ill-defined greenstone. One variety of the felspar rock contains grains of quartz, and another has a conglomerate or brecciated character. In the hills of Carwood, north-east of this cone, the sandstones are very felspathose, partially altered, and dip away in broken masses from the intruding rock; and the analogy between the phenomena observable around this little boss and those on the flanks of the Great Caradoc is complete. The south-western termination of the line of disturbance occasioned by the intrusive rocks along this axis is further traceable in several irregular dykes or small protrusions. One of these is on the sides of the Middleway lane, in the deep comb on the western side of Hopesay Common, where highly dislocated strata of sandstone and shale are thrown off a little boss of trap rock of very mixed characters, the mass being penetrated by veins of white calcareous spar, the whole much resembling a mixed calcareous and serpentinous rock, which I shall presently describe as occurring on the banks of the Severn near Cound Lodge. It may be remarked, that although it might be difficult to assign any precise age to the sandstone immediately in contact with the intrusive rock of this point, the broken knolls, with the contiguous strata tilted to the west, consist of the Ludlow

[1] The Rev. William Vernon Harcourt has directed his attention to the chemical changes produced in sedimentary rocks by the application of long-continued heat. He informs me that in the Yorkshire iron furnaces, where a variety of millstone grit is employed as the furnace-stone, after having been in long-continued contact with the molten metal, the stone undergoes a peculiar kind of fusion, not of the mass, but of the particles of which it is composed, the disseminated *felspar serving as a flux to the siliceous grains*: in some instances he has found portions of the stone converted into a mass of felspar regularly crystallized; in others, veins or nests of various crystals occurring *at intervals*, the intermediate substance of the stone being comparatively little altered. This circumstance Mr. Harcourt attributes, to the differences in the original texture or ingredients of the rock, which have occasioned the heat and volatile matter penetrating the substance of the stone, to produce similar effects in similar parts, however distant the one from the other. He states that the portions of the stone which have borne the strongest heat, *have entirely lost the fracture and characters of a sedimentary rock*, and assumed a high degree of density and hardness, which becomes greater in proportion to the presence of aluminous, ferruginous, or calcareous matter. Among other analogies, the modern parallel seems to explain how certain portions of sedimentary strata near the igneous rock may be slightly changed, while others more remote may be much altered.

formation, whilst the mass of Hopesay Common on the east is made up of the red and purple beds of the Caradoc sandstone.

The prolongation of the chief axis of the Caradoc System is, however, to be traced through the culminating point of Sibdon Hill to the village of Aston by occasional slight protrusions of highly indurated and broken beds of red sandstone, with very rarely a point of felspar rock. This axis finally terminates in the hill of Corton, where the Caradoc sandstone and grit have been described as tilted off on either side of a line of elevation. In a recent excavation for the foundation of a house on this hill, the dislocated strata were found to be based upon a rock of the same ambiguous character which marks the anticlinal in Sibdon and Aston Hills, a dark red, hard, felspathic rock, with a quartzose fracture, slightly tinged in parts with chlorite.

On the south-eastern face of Sibdon Hill and a little west of Sibdon House, there is, however, an outburst of unequivocal trap, which rises to the surface in three dykes more or less parallel, trending towards Wartle Knoll. Two of these, consisting of decomposing concretionary greenstone, are of slight thickness, with vertical and contorted beds of shale on their sides: the chief or central mass rises in an arch through the strata, which from its hardness and compactness was very valuable as a roadstone in this district, but was soon quarried out to a depth rendering further extraction too expensive. This rock is essentially dark-coloured, felspathic, and concretionary: the white felspar separating from the hornblendic base into small concretions, gives to the whole a spotted aspect. Another variety is so compact a greenstone that it may almost be termed basalt, and in it are minute concretions of quartz.

### "*Volcanic Grit.*"

Besides the intrusive trap and masses of altered rock, the Wrekin and Caer Caradoc throw off at a little distance from their flanks, bedded sandstones and grits, which although they sometimes contain organic remains, are in composition so analogous to the trap itself, that I designate them "volcanic grit." Mr. A. Aikin has alluded to this rock, as a micaceous sandstone nearly allied to greenstone, Geol. Trans. vol. i. Old Series, p. 212. There is a good section of these beds near the southern termination of the Wrekin. The stone is here of a dark green colour, and consists of the same materials which constitute greenstone and syenite, with a few fine scales of mica. The beds dip away from the trap at a high angle.

Again, on the eastern flank of the Caradoc, the same rock occurs in highly inclined strata, also hanging off from the intrusive ridge. It is well displayed at a spot about two hundred yards E.N.E. of the base of Little Caradoc, and is made up of grains of green earth and felspar, with some scales of mica, &c. Hand specimens of this rock would unquestionably be mistaken for trap. In other situations along the same flank of that ridge, the sandstone contains much decomposed felspar.

Somewhat further removed from the Caradoc, is a line of shelly sandstone, also ranging parallel to the main ridge and dipping away from it, in which the same composition is more or less perceptible, the aspect of the rock being on the whole entirely dissimilar to any sandstone of the secondary series hitherto described. This sand-

stone extends from the hills between Church Preen and the Hoar Edge, to Broome, Chatwall, &c., and is re-produced at intervals for some miles, extending to Cheney Longville, where it has been described as composing a part of the third formation of the Silurian System. These beds consist, for the most part, of slightly micaceous and very fine-grained sandstone, of a dingy olive-green colour; they contain casts of encrinites, trilobites, and mollusca, but if these fossils were excluded, the stone would be said to resemble a sandy claystone of the trap family.

These strata, however, mark the extreme verge of this class of deposits, for they are surmounted by the argillo-calcareous formation of Wenlock, neither in which nor in the overlying Ludlow rocks are there beds of similar structure.

As I have detected these sandstones, not only on the sides of the Salopian intrusive rocks, but also on the flanks of the Malverns and in other places where syenite and other trap rocks protrude, and as I have never observed them where there are no such rocks in the vicinity, I am induced to think they were formed during a period of submarine volcanic action, and that the materials are ashes and scoriæ given off during submarine ejections.

Such deposits must, it is evident, be now forming beneath the sea where submarine volcanic eruptions occur, and the mass of Graham Island, as well as the fine detritus resulting from similar causes, described by Capt. Smyth and others, as rendering the Mediterranean turbid, must have subsided in a manner directly analogous to that by which it is conceived this grit was accumulated.

That organic remains should occasionally be found in the ancient grit is strongly supported by modern comparison, for the eruption above noticed must have entangled the shells at the bottom of the sea, and many of the dead fishes noticed on the surface most probably were entombed in the subsiding ashes.

In this instance we have, therefore, a striking example of the value of studying existing operations, with a view to explain ancient phenomena[1].

I must first refer the reader to the fifth chapter for a general explanation of this subject, and to chapters 22, 23 and 25 for copious details and illustration of my views. The evidences there adduced are clear, that these volcanic grits were formed during the elaboration of the Lower Silurian Rocks, and were the *precursors* of great outbursts of intrusive trap along the principal fissures of eruption.

### *Period of Eruption of the Caradoc.*

If the volcanic grits are proofs of often repeated igneous action during the period when the Lower Silurian strata were accumulating, a singular outlier of Upper Silurian rock on the north-western flank of Caer Caradoc, distinctly proves that the amorphous trap of the main ridge was subsequently thrown up. Near the base of one of the

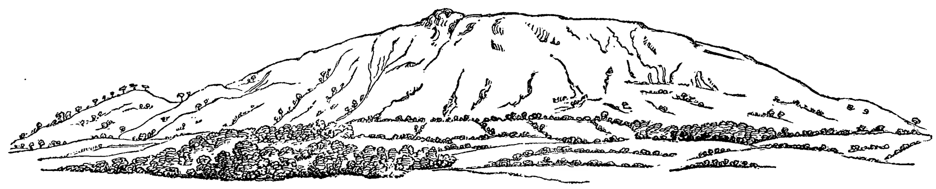
[1] See Lyell's Principles of Geology, 4th edit. vol. ii. p. 199, &c.

steepest acclivities of the chief hill, and close to the house of Botvyle, is a knoll about five hundred paces in length and two hundred in breadth, of impure limestone belonging to the middle portion of the Ludlow rocks. The strata are vertical, or dip 80° to the south, and strike in one part due east and west, in another 10° and 15° north and south of those points, their direction conforming to a buttress of the trap of Caer Caradoc, which advances towards Botvyle. (See Map.) Some of these beds are concretionary, others consist of thick, flaglike, impure grey limestone, containing fossils of the Aymestry or middle Ludlow rock, among which are *Terebratula Wilsoni*, *Pleurotoma corallii*, *Atrypa affinis*, &c. The limestone is for the most part much indurated and altered, and although it has been burnt for lime, it is now little used, the adjoining limestone of the coal measures at Le Botwood being of superior quality (see p. 93, *et seq.*).

Other strata, representing the Lower Ludlow rocks, and containing the *Asaphus caudatus*, are broken off from this insulated mass of limestone, and ranging nearly at a right angle to its direction, strike to the south-west, along the flank of the chain, occupying the low hills of Caradoc Coppice and New Farm. These Lower Ludlow beds, though exceedingly dislocated, are not like the limestone changed, being further from the intrusive rock. The altered mass standing on its edges, in an insulated position, amid rocks of much higher antiquity than itself, and adhering to the sides of an eruptive ridge, shows that the Ludlow formation was at one period continuously spread over this district, and that the Botvyle outlier is its only remnant, the underlying formations having been upheaved, and the overlying denuded. (See Pl. 31. f. 4.) No portion of the highly convulsed region laid down upon the annexed map offers so striking an example of the extent of the disturbing forces as this insulated mass of Ludlow rock; dissevered from similar deposits by an interval of five miles and encased in a gorge between two mountain masses; one a volcanic rock which has thrown the Upper Silurian beds into mural position, the other slaty rocks of the Cambrian System (the Longmynd). The latter, indeed, is also penetrated by numberless intruders of trap, which we shall presently consider. In the meantime, the phenomena at Botvyle prove, that the trap forming the main ridge of the Caradoc has been evolved posterior to the consolidation of the Silurian System.

This period of elevation was synchronous with that which threw up the Silurian strata on the flanks of the Wrekin, and was antecedent to and distinct from those eruptions which on lines more or less parallel, subsequently affected the carboniferous system, as will be shown in the following pages.

S.W. N.E. 28.



*Primrose Hill.* *The Wrekin seen from the East.* *The Ercal rises from this depression.*

*Trap Rocks of the Wrekin, Lilleshall Hill, &c.*

Rocks of trappæan or igneous origin intersect the strata at numerous points on the left bank of the Severn. In Haughmond Hill they cut through the Cambrian System; in the Wrekin and its dependencies, the lower edges of the Silurian System; in the districts of Little Wenlock, Ketley, &c., the coal-field; and at Lilleshall, both the Silurian rocks and the carboniferous limestone. Of the trap of Coalbrook Dale we have already spoken (p. 109.), and of that of Haughmond Hill we shall hereafter treat in connexion with the Cambrian deposits. Let us in the meantime review the group of the Wrekin. (Pl. 1. fig. 11.) This elliptical hill, rising into a narrow crest, is about one mile and a quarter long, and its culminating point is 1330 feet above the sea. In Ercal Wood, the north-eastern prolongation of the axis of the Wrekin, are other rocky masses of similar composition, the highest point of which is seven hundred feet above the sea. They extend in a broken and rugged outline upwards of a mile towards the north-east, and terminate near the high road from Wellington to Shrewsbury. They are separated from the Wrekin by a narrow gorge, and on their south-eastern flank rises a separate hill of about equal height, called Madox Hill, the axis of which is parallel to the Ercal and the Wrekin. Beyond the south-western extremity of the Wrekin, and separated from it also by a depression, is a conical knoll, called Primrose Hill. (See left side of the wood-cut.) Designating all these hills under the name of the Wrekin, they may be described as essentially composed of rocks of igneous origin, having upon their flanks various strata of the Silurian System, which, in contact with the trap, have undergone (as at the Caradoc) great changes in mineral character.

The rock most unequivocally of igneous origin, is a pink, deep red syenite, consisting principally of compact felspar, with some white quartz, a few crystals of common felspar, and occasionally disseminated chlorite. In the Ercal ridge the chlorite prevails, so as to give the rock a green aspect, small crystals of iron pyrites being also present. In the extensive road-stone quarries, near the Hay Gate, at the northern termination of the hill, are several varieties of compact, pink, and purple felspar, some of which are finely concretionary, with passages into a fine granular structure; others consist of a very hard compact mass, which in fracture bears a quartzose character, the cornéen ? of French mineralogists. In Madox Hill is a fine-grained, pink syenite, and also a rock made up of felspar and green earth, with some veins of carbonate of lime. The summit and centre of the

Wrekin, properly so called, consists of flesh and brick red, compact felspar. This red felspar rock is particularly well displayed in the gnarled points, called the "Raven's Bowl" and the "Bladder," the south-eastern summits of the ridge. One of the varieties of this rock has been described by Mr. Aikin[1] as a cellular claystone, the cavities in which have been so compressed as to give the rock a waved and striped appearance. (Geol. Trans. Old Series, vol. i. p. 2.) Owing to the verdant slopes upon the summit and sides of the Wrekin itself, there is little opportunity of detecting all the varieties of which it may be composed, but towards the centre of the hill are some protruding knobs of dark green compact felspar, passing in one part into granular felspar, in another containing crystals of common felspar and small grains of quartz. The conical knoll of Primrose Hill at the south-west end of the Wrekin, is a deep red syenite, graduating on the western side into compact felspar rock, coloured green by chlorite. Of this rock are several varieties, some of which assume a finely laminated arrangement, others are very imperfectly laminated, and are mottled dark green and pink.

The stratified deposits through which the trap rocks of the Wrekin protrude, are of the same age as the Caradoc sandstone: varieties of these strata are to be seen on the flanks of the Ercal, Madox, and Primrose Hills, in highly inclined and vertical beds, and the lithological characters are in some instances highly changed, as on the flanks of the Caer Caradoc. The most striking example of alteration is where the sandstone, preserving its bedded form, is changed into granular quartz rock, many specimens of which being made up of pure white quartz, with particles of decomposed felspar, are scarcely to be distinguished from primary granular quartz rock. This quartz rock in the state of a brecciated aggregate, prevails in the knolls between the syenite of the Ercal and that of Madox Hill. A beautiful example of this quartzified grit and sandstone is on the eastern, steep, woody side of the Wrekin, opposite to Willymoor. The original lines of lamination are distinctly preserved, the beds varying from two inches to two feet in thickness, and dipping 60° east-south-east, or away from the trap rock. Quarries opened for the extraction of stone used in the manufacture of china[2], expose the sandstone in various degrees of alteration and traversed by a great number of symmetrical joints. On the faces of some of these beds I perceived impressions resembling the casts of shells and ramose bodies, probably coralline, but they were too indistinct to be even generically determined.

There is also much of the quartz grit on the western slopes of the Wrekin, so that the same effects have been produced in the sandstone on both sides of the trappæan ridge. Again, on the south-eastern face of Primrose Hill are quarries, which exhibit in highly inclined strata, a passage from a coarse granular sandstone, in parts micaceous and schistose on the exterior, to a hard rock, consisting principally of grains of white and grey quartz, with particles of decomposed felspar. I have yet described only that ridge which in strict geographical language is the Wrekin, but there are other trap rocks which rise to the surface through the adjacent sedimentary deposits, in lines parallel to the main direction of the principal eruption. On the north-western face of the hill, a long talus of heavy clay and detritus obscures the relations of the strata for nearly two miles, but in the meri-

[1] Geological Transactions, vol. i. p. 210, Old Series.

[2] Coalbrook Dale.

dian of Wrockardine, Rushton and Charlton, other lines of trap are met with, the major axis of which, trending equally from north-east to south-west, has a greater length than that of the Wrekin, being traceable in protruding lumps which here and there rise to the surface in the tract between Admaston Spring and Cound Cottage on the Severn. From the knolls above Admaston to near Wrockardine, the chief rock is the same compact red felspar as that of the Wrekin. At Wrockardine is another variety, composed of green earth, felspar, hornblende, and a little carbonate of lime. At Lea rock, where cut through by the new Holyhead road, besides the pink-coloured compact felspar, there is a mottled rock of the same materials with disseminated epidote, and this passes into a porphyritic clinkstone. At Rushton, the trap which appears in and near the village, consists of felspar, epidote, quartz, &c., and near it are quartzose altered sandstones, and veins of pink and white quartz rock. At Charlton Hill there are several varieties, such as, 1. Porphyry, i. e. grey compact felspar, with small crystals of common felspar; 2. Pink compact felspar rock; 3. Greenstone, almost basaltic; 4. Dingy green-coloured rock of felspar, mixed with chlorite or green earth; 5. Pink and brown mottled compact felspar, with grains of quartz (cornéen?). These rocks occupy the chief part of the hill above Charlton Mill, flanked by highly inclined, and altered strata of shale and sandstone, through which they protrude, a considerable mass of the latter being converted into quartz rock, (on the south-western slopes of the hill). From this point to the valley of the Severn there is a considerable fall in the surface of the country, and the stratified rocks are obscured by gravel, the depression being occupied on its western side by the Lower New Red Sandstone of Wroxeter, which extends to Shrewsbury; and also by the little patch of coal measures at Dryton, already described, p. 93. In the bed of the Severn at Cound Cottage, the line of the trap rock was formerly exhibited in irregularly projecting lumps, which as they impeded the navigation have been nearly destroyed, but when the river is low, their remains can be detected upon the right bank. The rock is here a dull green trap of a very mixed character, with steatite and veins of calcareous matter, some of it approaching to serpentine. The axis of this lineof trap is further traceable across Cound Moor, by vertical and tilted beds of the Caradoc Sandstone.

The line of eruption, extending from Admaston to Cound, is not a prolongation of the Caradoc, but forms a third and separate parallel between it and the Wrekin. (See Map.)

### "*Lilleshall Hill,*" (Pl. 1. fig. 15.)

This hill is nearly half a mile long, and about three or four hundred paces broad, rising to a sharp summit about three hundred and fifty feet above the sea[1]. Its axis trends from north-east to south-west, and it is therefore parallel to that of the Wrekin. The greater portion of the hill, particularly the central and eastern, is a deep red syenite, some varieties of which are coarse grained, others exceedingly fine, the latter passing into granular and compact felspar, one of the knotty summits being a perfect hornstone. On the whole the rock is similar to that of the Wrekin.

On the north-western face the trap is extensively quarried for the roads, the chief mass consisting of slaty, pale green, compact felspar, coloured red externally by iron; and further to the north

[1] The summit of Lilleshall Hill has recently been ornamented by a monument, erected to the memory of the late Duke of Sutherland.

the bedded structure becomes still more decided, and the rock is a thin, flaglike claystone, dipping eighty degrees north-west, in highly inclined beds. Towards the southern end of these great quarries, the flaglike rocks are traversed by several dykes running from north-west to south-east, issuing as it were from the body of the hill. The broadest of these dykes is about ten feet wide. They are also felspar rocks, of dingy green and greenish grey colours, of a rough fracture, slightly resembling certain trachytes, and are in part coloured purple by the oxide of iron. The inclosing or contiguous masses of rock are much harder than the dykes themselves, presenting the appearance of having been altered by the injection of the latter. Similar masses run in devious directions through the trap of the Caer Caradoc. As both the mass of the hill and the dykes, are rocks of igneous origin, we have only to suppose that the latter are posterior injections filling up chinks and cracks, and cutting through the body of trappæan or volcanic dejections[1]. The trap of Lilleshall Hill has risen through thin-bedded sandstones, which are apparently of the same age as those of the Caradoc. This sandstone is seen in several parts of the village of Lilleshall, particularly near the church, where it is highly inclined, and unconformable to the carboniferous limestone. Some beds belonging to the bottom of this limestone rise up upon the north-western face of the hill from beneath the adjoining large mass of that rock. (see p. 107.) Although the relations of these beds are not clearly displayed, they have certainly been affected by the trap, since in the prolongation of the axis of the hill to the north-east, the limestone is thrown off to the north-east and north-west, the axis of elevation being directly upon the prolongation of the line of eruption of Lilleshall Hill, and also in the continuation of the great Lightmoor fault by which the whole coal-field and the underlying Silurian rocks have been so powerfully affected. (See Pl. 29. f. 15.)

Coupling the preceding observations with what has been said concerning the trap rocks and dislocations of Coalbrook Dale and the Clee Hills, it may be affirmed, that this district in Shropshire furnishes proofs of the alternate play and repose of volcanic action during very long periods. These evidences demonstrate, 1st. That volcanic grits were formed during the deposition of the Lower Silurian strata; 2nd. That the Upper Silurian rocks and Old Red Sandstone were accumulated tranquilly without a trace of contemporaneous eruptions; 3rd. That after their consolidation, the last mentioned deposits were dismembered and set upon their edges by vast outbursts of intrusive trap; 4th. That the carboniferous system was deposited after the older strata had been upheaved; 5th. That subsequent dislocations, including some of the most violent with which we are acquainted, took place after the accumulation of the coal measures, and Lower New Red Sandstone.

[1] If an illustration of this be required, the reader is referred to the writers who have described Vesuvius. On the principal sides of Monte Somma, the ancient and extinct crater of Vesuvius, are numerous dykes of lava penetrating in vertical and oblique directions, the former coulées and dejections of volcanic matter. These facts were first pointed out to geologists by Sir James Hall. They have since been dwelt upon by Necker de Saussure and other writers, and more recently by Mr. Lyell. I may here remind my readers, who are not geologists, that the difference between the volcanic action at Monte Somma, and in Shropshire, consists in this, that the eruptions in the former case are sub-aërial, in the latter they were sub-marine.

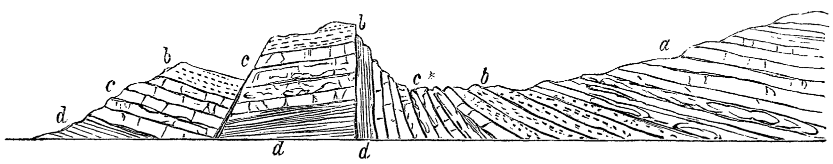
*Dislocations of the Silurian System and adjacent rocks in the district of Ludlow and Wenlock.*

Returning to the district in which the rocks of this system have been described and where no trap rocks are visible, the strata of each formation trending from south-west to north-east, succeed each other at low angles, generally inclined towards the south-east. In the parallel of Wenlock Edge, the Ludlow rocks, the Wenlock limestone, and the Caradoc sandstone, present a regularity of stratification and succession rarely, indeed, seen in the secondary or tertiary deposits. Even there, however, we have abundant proofs of great dislocation, principally where these rocks are traversed by the rivers Severn, Onny, Teme, and Lugg. Such fractures are usually marked by much local divarication in the strike and inclination of the beds. For example, on approaching the Iron Bridge or Coalbrook Dale from the south-west, the Wenlock limestone after various undulations, is found advancing from the Gleedon Hills on the right bank of the river in a remarkable sharp ridge, called Benthall Edge, and trending E.N.E., W.S.W. At the north-eastern termination of that edge the beds dip 18° to the south-east, being there brought into unconformable contact with the coal measures by the great fault of Broseley. (See Map.) On the left bank of the Severn the same beds of limestone are thrown up into another ridge, called Lincoln Hill, which though not so lofty as that of Benthall Edge, is sharper and narrower, the strata striking nearly N.E., S.W., and being inclined at angles of 50° and 60°. Not only does this great discrepancy in the angle of inclination mark the existence of a transverse fault, indicated by the deep fissure through which the Severn escapes, but the fault is further proved by the divergence in the direction of the strata on the opposite banks, those upon the left bank having a strike of 15° or 20° different from that of the beds on the right bank. By this derangement, the Wenlock limestone of Lincoln Hill is accidentally brought into *conformable* apposition to the coal measures; thus offering a marked exception to the relations usually existing between rocks so widely separated in the epochs of their formation; indeed the same beds of the coal-field wrapping round the escarpment of the Silurian rocks on the sides of Coalbrook Dale, are there placed in nearly horizontal positions upon the edges of the highly inclined strata of the Wenlock shale, distant only two miles from Lincoln Hill. The greater number of these dislocations have taken place subsequent to the deposition of the carboniferous rocks, since the latter have been powerfully affected by many great faults in common with the Silurian rocks on which they repose.

Without noticing the minor breaks and faults in the upper Silurian rocks, let us pass to the south-western extremity of Wenlock Edge near the gorge of the river Onny, where the strata are again much broken up. At Dinchope, the Aymestry limestone and associated Ludlow rocks are thrown over, dipping to the south-west and north-east, in a short, low ridge, at right angles to the general strike of the strata. The same beds are upcast to a much higher level, forming the bold cliffs of

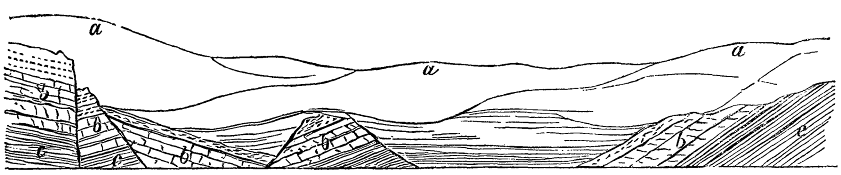
Norton Camp, on the left bank of the Onny, and dip due east 15°. In the still higher ridge on the opposite bank of the river, called View or Yeo Edge, the Aymestry limestone again resumes the prevalent south-westerly strike, the beds inclining 8° south-east, thus proving a great fracture nearly at right angles to the chain, by which the limestone has been dissevered, and thrown into the divergent directions which it now occupies on the opposite banks of the river. Between the transverse valleys of the Onny and the Teme, the strata composing Mocktree Forest, are arranged with tolerable regularity, the Ludlow rocks dipping to the east-south-east and south-east at slight angles. There are, however, many exceptions to this regularity, each comb or recess in the escarpment being, more or less, the seat of a minor fault. In several of these combs the Aymestry limestone is exposed.

One of the most remarkable of these dislocations is at the Old Craft lime-works at Mocktree Hays, where there is a complicated fault, by which a mass of the Aymestry limestone (c*) has been thrown into nearly a vertical position, the lower beds abutting against the edges of a mass of similar limestone, which has been thrust up between the highly inclined strata and another dislocated mass. Each of these bands of limestone (c) is capped by the stratum (b) charged with *Terebratula navicula*, and underlaid by the pendle beds (d) of the Lower Ludlow Rock.




29.

Other dislocations producing considerable changes of level are seen on the sides of the comb by which the road from Leintwardine to Ludlow passes, of which this wood-cut may convey a general idea, the observer being supposed to be placed on the west of the escarpment and looking eastwards towards the Ludlow Hills.



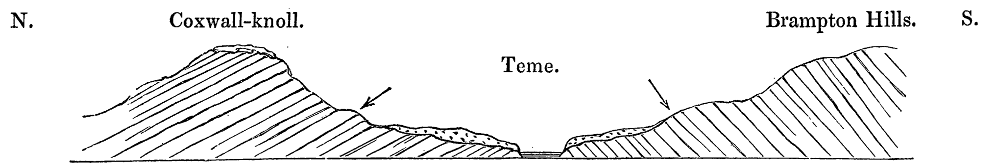

30.

The gorge of the river Teme, at Downton, is the result of a third great transverse fault, like the others affording evidence of a very powerful dislocation, by which the strike and inclination of the beds is completely altered, for instead of an inclination of 8° or 10° to the south-east, as exhibited in most of the hills of Mocktree Forest, the Ludlow rocks and included limestone on the banks of the Teme are wrenched round, striking east and west, and dipping to the north in Tatter Edge at an angle of 40°, and in Downton Gorge at 20°. The convulsion which gave rise to the gorge of the Teme, is indeed, the same as that which determined the form of the Ludlow promontory.

An axis of elevation ranging south-west and north-east, (from Wigmore to Ludlow,) has elevated the Ludlow rocks into that remarkable promontory, the strata of which dip to the north, east, and south-east. The elevatory forces having acted with the greatest intensity along the interior or axis of the promontory, the shale of the Wenlock formation has been there brought up (Pl. 31. f. 5.); and being of less firm structure than the younger strata forming the external ridges, has been worn into a deep valley in which there are only a few low hills. Towards the extreme point of the promontory on which the castle of Ludlow stands, the intensity of the elevatory action seems to have diminished, the youngest member of the Silurian System being alone apparent, dipping under the Old Red Sandstone. (See Map.) This elevated mass is indeed a fine example of a valley of elevation, and like most of the tracts so called, it is strictly also a valley of denudation; the lowest strata having been deeply excavated, leaving in the centre a level flat called Wigmore Lake, surrounded by the villages of Aston, Leinthall Starkes, Wigmore, and Burrington. This subject of valleys of elevation, will be so amply illustrated in a subsequent chapter on the valley of Woolhope, that it is here unnecessary to dwell further on the phenomena; and the probable condition of this depression in more recent epochs, will be spoken of under the head of alluvial phenomena in the concluding chapters. In the meantime I may observe, that this tract conveys to the geologist a clear conception of the abrupt manner in which elevatory forces have affected the strata, particularly when viewed from the high grounds of St. Mary's Knoll and the Vinnals, where two sides of the promontory meet at an acute angle. On one side (see Pl. 31. fig. 5.) is the sharp ridge of Brindgwood Chase, composed of the Ludlow rocks dipping north at angles of 30°, and beneath this escarpment a lower line of knolls, occupied by the Wenlock limestone and shale extending to Burrington, the strata passing under the Ludlow rocks. On the other or south-eastern face of the promontory, the movement has not been of this simple character, but has produced a double system of ridges, in which the Ludlow rocks and Wenlock limestone are each repeated, between an outer ridge ranging by Orelton Common and Croft Ambrey, and an inner ridge occupying Gatley Coppice. In the escarpment of the outer ridge, the angle of inclination increases with the height of the hills, for at Whiteway Head the beds of Aymestry limestone dip 45° to the south-east. (See vignette, p. 241.) A section across this promontory from north to south, as expressed in Pl. 31. f. 5., explains more intelligibly than pages of writing, the relations of this interesting tract, which in geological language may be called a saddle, having a double flap on the south-eastern, and a single on the northern side. Although in general the strata of the Ludlow rocks dip outwards from this promontory, passing conformably and at low angles beneath the Old Red Sandstone, there are some exceptions to this rule, caused by partial dismemberments. Such, for example, are seen in several undulating knolls near Richard's Castle, and at the "Bone Well" near that village, where a mass of the rock is thrown across the general direction of the strata,

and dips to the north-east. The small outlying ridge of Ludlow rock and Aymestry limestone which occupies Caynham Camp and Tinker's Hill, has been upcast on a line precisely parallel to the axis of the Ludlow promontory, and like all the adjacent ridges it has been broken by a transverse fissure, now occupied by the Lutwiche Brook. (see p. 241.)

The last of the transverse gorges we have to notice in the Ludlow district, is that by which the Lugg escapes from the Silurian rocks at Aymestry into the low country of Old Red Sandstone near Leominster. Hence, as in every case cited, the river flows in a fissure caused by dislocation; for the limestone on the left bank is thrown up into the Poor-house wood, dipping slightly to the south-east, and passing beneath the Old Red of Lucton, whilst the same beds at the village of Aymestry on the right bank of the river dip to the south. Similar instances of transverse fracture are found in all the strata traversed by the above-mentioned rivers when we ascend any of them towards their sources. Thus the strata on the opposite banks of the Teme, west of Leintwardine, are tilted in divergent directions. He who, combining antiquarian with geological research, seeks to determine the spot, where Caractacus and his Silures made their last struggle against the Romans, may mark the line of dislocation in which the Teme flows, by crossing from Brampton Bryan to Coxwall-knoll[1]. The strata on the south bank dip 60° to the south-south-west, and those on the north, which support the supposed camp of the British chief, are inclined northwards 40°, as represented in this wood-cut.




31.

Other similar powerful dislocations are again seen between this site and the town of Knighton, and the whole of the course of the Teme, if followed to its sources, equally abounds in them. Again, there is no finer example of this phenomena than where the Onny escapes from the upland and mountainous tract of Shelve and Linley. (See vignette, chapter 22.)

The principal derangements of the Silurian rocks in one district have alone been explained; and from these statements, it appears, that every river course transverse to the direction of the strata, has been determined by the fracturing of solid masses, which have been once continuous. Although the description from p. 237 applies to a district in which no trap is visible at the surface, we cannot view the ridges of Ludlow and Wenlock as placed between two great fissures of volcanic outburst, the Clee Hills

[1] This historical point is illustrated in the Appendix, where it is shown that Coxwall-knoll could not have been the scene of the last battle of Caractacus.

on one side, the Caradoc on the other, without believing that the fractures of the Silurian rocks were intimately connected with those eruptions. This subject will, however, be further illustrated in the sequel.

In addition to the deep fractures which have become river gorges, each ridge is fissured, both longitudinally and transversely, by a number of minor faults, which are indeed so common in all ancient rocks, that their existence would scarcely be worth noticing, did not many of them show the manner in which they have become the seats of springs and small streams, as will be detailed in the ensuing chapter.

By throwing the eye over the map, the reader may obtain some notion of the frequent solution of continuity between the ends of the strata. A few of these have been laid down on the map, to explain the extent to which the formations have been affected, in one of the *least* disturbed of the districts over which the Silurian System ranges.

I would further only remark, that beyond the south-western extremity of the axis of elevation of the Caradoc sandstones at Corton, the formation of the Ludlow rocks, though without any traces of Aymestry limestone, is repeated in the hills of Hoptown, Brampton Bryan, &c. Some of these are elevated undulating masses, which fold over and pass under the detached fields of Old Red Sandstone of Norton on the south-west, and of the forest of Clun on the north-west. In others, however, the beds are thrown up at very high angles by powerful lines of dislocation occupying more abrupt positions than any deposits in the immediate vicinity of Ludlow, as for example in Hopton Titterill, where they are *vertical*, with a strike from north-east to south-west. This remarkable upcast (the effect probably of the outburst of the Caradoc,) serves to explain how the Old Red outlier of the forest of Clun has been severed from the main body of that system. (See pp. 190—193.) Further accounts of the dislocations by which the strata of this age have been affected in their prolongation to South Wales, will be found in the pages in which the structure of these tracts is described, and usually following, as in this case, the description of the trap rocks of each district.

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### "*Outliers of Ludlow Rocks.*"

"*Tinker's Hill and Caynham Camp,*" "*Linley and Dean,*" *near the Iron Bridge.*

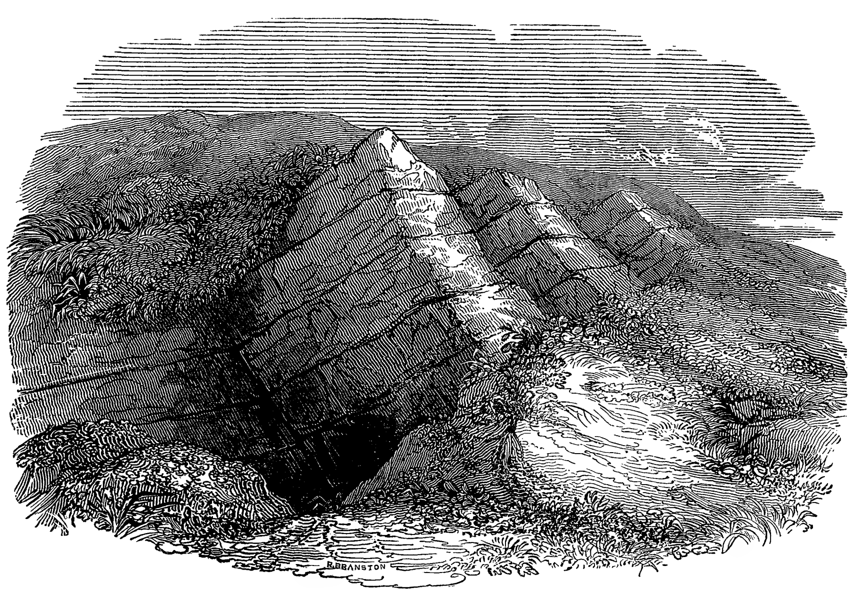
A narrow outlier of these rocks rises from beneath the Old Red Sandstone, one mile and a half south-east of Ludlow. It is about two miles in length from north-east to south-west, and is parallel to the main direction of all the Silurian deposits. The Lutwiche Brook, a tributary of the Teme, flows through a gorge which bisects this little ridge, the south-western half being called Tinker's Hill, the north-eastern Caynham Camp, their height being respectively 500 and 600 feet

above the sea. Tinker's Hill rises on the south-west from the left bank of the Teme, near the Saltmoor Well, and is chiefly composed of Upper Ludlow rock, the strata of which, though dipping only 5° or 6° to the south-east at the south-western or low end of the hill, are thrown up to angles of 40° and 45°. By this upcast a band of the Aymestry limestone is brought out on the escarpment, and was formerly much worked, being in some quarries about forty feet thick. It consists principally of small nodules enveloped in sandy calcareous shale, but occasionally united into thick flaglike beds of grey or bluish earthy limestone. This sandy and argillaceous limestone is much preferred to the purer limestones as a sub-aqueous cement, and for ceiling and plaster. Among the fossils is the *Terebratula Wilsoni* and others characteristic of the limestone, though I have not found the *Pentamerus Knightii.* This shell, so prevalent in the main escarpment, becomes very rare in the denuded patches on the exterior slopes of the Ludlow rocks, as they descend towards the Old Red Sandstone in the vicinity of Ludlow, (Whitcliffe Woods, Sunny Bank, Palmer's Cairn, &c. &c.); its disappearance therefore in an outlier still further removed from the principal range of the rock is what might be expected. There can, however, be no doubt of the age of this limestone, for at Caynham Bridge the strata pass up into true Upper Ludlow rock charged with most of its peculiar fossils. The gorge in which the Lutwiche traverses the ridge, is a disruption of the strata, for on the right bank, a large mass of limestone is thrown across the prevalent direction, dipping 35° south-south-west; whilst in Caynham Camp on the left bank, the north-easterly strike is preserved, and the same rocks are at a different level dipping to the south-east. The north-eastern extremity of the hill, on which was the ancient camp, is round, the strata dipping inwards with much contortion. In consequence of the destruction and denudation of the surrounding strata, there are no evidences of the precise relations of this ridge of Ludlow rocks to the Old Red Sandstone through which it has been upcast, except on the side of the brook between Poughhill and Caynham Bridges, where the Old Red Sandstone is highly inclined; and again in a small knoll between Steventon and Tinker's Hill, where red and green marls and red sandstone are almost vertical, thus affording proofs that their dislocation was affected by the movement which elevated the ridge of Ludlow rocks, since similar beds of Old Red Sandstone appear on the adjoining banks of the Teme, resting at very low angles and undisturbed, upon the Upper Ludlow rock.

The saline well in the flat at the south-western end of Tinker's Hill, issues most probably from the Ludlow rock, as it is in a line between the ridge described and a part of the bed of the Teme in which the same strata emerge from the thick cover of gravel and clay which overlay them in the neighbourhood of the well.

Two other small contiguous outliers of Ludlow rock, occur on the right bank of the Severn near the southern termination of the coal-field of Coalbrook Dale. The most southern rises from beneath the Old Red Sandstone at Lindley, and throws off to the north-east and north-west poor and thin coal measures. The more northern and more prominent of the two is nearly two miles long, and about a quarter broad, extending from Dean on the west-north-west, by Darley and Frith Coppice to near the Severn on the east-south-east. This mass is flanked by the upper coal measures containing the freshwater limestone. (see p. 100.) At Dean Corner the beds consist of thin lenticular masses of impure limestone and shale, probably equivalents of the Aymestry limestone. They contain *Terebratula Wilsoni* and other fossils, and dip at a low angle under the coal measures. On the sides of the woody Frith Dingle, the same and also lower strata are exposed in horizontal layers, some of which are sandy and flaglike, and seem to represent the Upper Ludlow rock; others consist of flattened slightly calcareous spheroids, inclosing *Terebratula Wilsoni, T. affinis,* &c.

The appearance of these outliers of Ludlow rock near Broseley are of theoretical interest, as showing that the formation has extended under the coal-field; whilst there is great reason to think that the Old Red Sandstone thinned out towards the north, and that the carboniferous deposits near the Iron Bridge, may have been originally deposited upon Upper Silurian Rocks.



*Whiteway Head, from a drawing by Mr. R. W. Evans* (Aymestry Limestone, beds dipping to the S.E.).

# CHAPTER XX.

## SILURIAN SYSTEM (*continued*).

*Joints of the Silurian Rocks.—Landslips.—Wells.—Agricultural characters of the Silurian System.*

### *Jointed structure of the Silurian Rocks.*

THE subject of joints has engaged the attention of many geologists. Even in the early days of the science, De Saussure observed them in the rocks of the Alps, and the phenomenon was not unnoticed even by our old native writers. Morton, for instance, in his Natural History of Northamptonshire, describes long joints or fissures, as distinguished from "gutters, gulf joints, &c.," and distinctly points out their great use to the quarriers, p. 124. to 136. In recent times MacCulloch attempted to give an explanation of the joints in granite founded upon crystalline laws. Mr. Enys, followed by Mr. Fox, described the granite joints of Cornwall, and showed that they had given directions. (Phil. Mag. vol. ii. Third Series, p. 321.) Dr. Boase has written much upon

the joints of the same district, though he has not separated them from veins, while Mr. De la Beche and others have contributed to increase our knowledge of this difficult branch of geological inquiry.

Professor Sedgwick, in an able original memoir, has recently described those infinite separating planes which constitute slaty cleavage, and has clearly pointed out the distinction between them and the divisions of which we are now treating. Professor Phillips has, however, more than any other geologist directed attention to *joints*, and has done great service in methodizing the inquiry[1]. Seeing the surprising regularity of the direction of the master joints in the north of England, where the prevalent direction of the strata is from north to south, he suggested that the east and west direction of the former might have been communicated by some general polarizing or electro-magnetic influence.

Once roused to a sense of the importance attached to jointed structure, the geologist will find a new source of interest in every face of rock; he must now, indeed, perceive that it is not enough simply to observe the strike and dip of the strata, he must also note the direction and measure the angles of their joints.

Referring to the table in the appendix for detailed observations, I will here merely state that the Silurian rocks contain, for the most part, two sets of prevailing joints, ranging in lines nearly *diagonal to the strike*, or axis of elevation of the strata. These diagonal divisions are usually symmetrical, and preserving precise relations, so intersect each other, as to present a number of *salient and re-entering angles* in the escarpment of every freshly opened quarry, as represented in the above vignette. They are generally vertical (or nearly so) to the surfaces of the beds; by which arrangement the rock is split into a number of lozenge-shaped masses, which are more or less well defined, according to the clearness and precision of the faces of the joints.

In some chains, indeed, but very seldom in this region, there are long fissures either coincident with the line of elevation, or nearly at right angles, i. e. in the same direction as the dip of the strata. These doubtless may very frequently have resulted from elevation of the strata "en masse," and they must not be confounded with the symmetrical joints of which we are now treating[2].

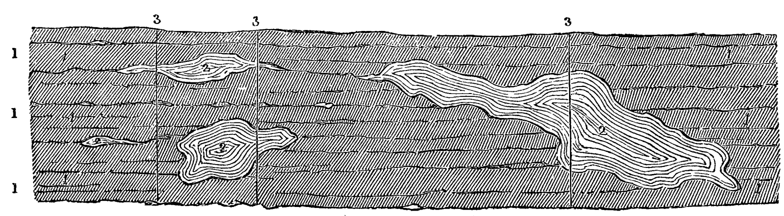
I therefore confine my remarks to the dominant joints, which in the ridges under consideration have fixed relations to each other, though those directions change with every variation of the strike of the strata. Allusion has been previously made to these joints as forming the backs of the quarries in the manner represented in the above vignette. They are the natural fissures by which the quarrymen are more

[1] See Phillips's Geology of Yorkshire, vol. ii. p. 90., and the same author's Guide and Treatise in Geology. In these works the subject of joints is ably treated.

[2] These fissures come more properly within the class of phenomena to which Mr. Hopkins has recently so well directed attention, and are more naturally connected with the preceding observations upon dislocations, entirely dependent upon lines of elevation.

assisted in their labours than even by the division of the mass into beds, for as the master joints extend to great depths, often traversing all the strata in straight and well-determined lines, they are not only the greatest aids in the extraction of blocks of stone, but also the surest guides for the line of work. In fact, if a sufficient number of joints cross each other diagonally to the strike, and at right angles to each other and to the laminæ of deposit, it is manifest, that the mass of rock so affected is split into symmetrical blocks; and as the faces of the joints are smoother and more regular than the surfaces of the beds, they are ready-made cleavages which help the quarryman's labours. The joints of the Silurian rocks are, for the most part, straight-cut chinks, either slightly open, or filled with a little shale. Wherever sufficiently open to be pervious to water, (as is frequently the case,) they present weathered faces even when first cut into in a quarry, and hence also it is, that the small concretions exposed on their surfaces, are constantly found to present certain lines of swallow holes, previously mentioned as common in the vertical faces of the Ludlow rocks, the less coherent concretions having disintegrated, even in subterranean positions, by the access of water, which has percolated for ages through these natural channels.

Although the time has probably not yet arrived when we can distinctly assign a cause for the formation of such joints, we may in the first instance endeavour to define the epoch of their formation by reference to other phenomena. It has been pointed out, that the Upper Silurian rocks, though in many parts deposited in straight bedded layers, composed of varied materials, are also very prone to concretionary structure. That structure was also shown to interfere abruptly with the laminæ of deposit, and so to truncate them, that there can be no doubt, the concretions were formed by some chemical or electric action after the first aggregation of the surrounding strata. In this way, therefore, we obtain evidence of two distinct successive operations as expressed in this wood-cut.



33.

First the successive deposition of the materials composing the beds 1, 1; secondly, the arrangement of these materials so as to occasion particles of similar matter (limestone for example, 2, 2,) to unite and form concretions distinct from the other laminæ of deposit. But besides the beds and concretions, the joints of which we are now speaking, are proofs of a *third* modification in structure, subsequent to both the others. This is established by the fact, that the joints 3, 3 not only cut through the beds 1, 1, but also through the concretions 2, 2. This is well seen in many deep quarries of the Wenlock limestone, particularly at Lincoln Hill, near the Iron Bridge, where the joints descend

through both the surrounding beds, and the large included concretions or ball-stones, enabling the workmen to contend more easily with these hard sub-crystalline masses. It is thus demonstrated, that such joints resulted from one of the *last* changes superinduced upon the strata after their deposit. As the same method of proof led Professor Sedgwick to show, that the cleavage peculiar to slates is one of the last changes which that description of rocks experienced, it might seem that joints and slaty cleavage are of the same class of phenomena. That author is, however, of opinion, that although they have both been caused by crystalline forces, joints and cleavage planes are to be clearly distinguished from each other, and numerous confirmations of the truth of this observation will be detailed in the subsequent pages, in describing the Silurian rocks of South Wales; where mountains affected throughout by slaty cleavage are shown to be as distinctly jointed as these now under consideration (see particularly the chapter on Caermarthenshire). That these different effects may be due to the same cause is rendered more intelligible by reference to somewhat similar phenomena. For example, in a six-sided prism of quartz the planes of cleavage are distinct from those of the prism, so that while it is impossible to cleave the crystals parallel to the plane of the prism in the same way as slaty rocks cannot be cleaved parallel to the joints, so the quartz crystal, like the older schists, may be cleaved *ad infinitum* in the direction of the cleavage planes. Joints, indeed, have one property which alone eminently distinguishes them from slaty cleavage: the latter often maintains an unity of direction and precision of parallelism, cutting through large regions, independent of the direction or inclination of the strata; while joints according to my observations invariably *alter* their direction with every change in the axis of elevation.

Judging from the known crystalline tendencies of various mineral substances, we cannot doubt, that the composition of differently constituted masses has had a very perceptible influence in predetermining *symmetrical* joints. Thus in all rocks composed of a mixture of lime, clay, and sand, (impure calcareous rocks,) or in argillaceous or sandstone strata, provided they are hard, joints are frequent and neatly defined; but in the same masses when incoherent, the joints are few, and so irregular in their direction as seldom to be referrible to any given forms. Hence we may infer, that where the strata have obeyed certain chemical laws, the cleavages are perfect, or approach those of crystalline bodies; but where those laws have acted less perfectly, they are less defined. Should it be contended, that the direction of the joints must have been connected with the elevation of the strata, (as without this hypothesis it is difficult to conceive how the joints could have preserved such symmetrical relations to the axis of elevation,) it might be replied, that although the directions of the joints vary with the dislocations of the strata, the different divisional planes may be all found to coincide, provided the disturbed strata be readjusted in their original positions. Now some of my observations would lead me to think that rocks of every age, if only hard and of a suitable composition, have a jointed structure the result of *crystalline* action, and that

the divergent directions in which the joints are arranged is the consequence of the *mechanical* process of elevation. On the other hand other data seem to render it probable that these two causes so distinct in themselves have sometimes cooperated to bring about the different directions of the joints. The latter inference is, indeed, forced upon the mind on examining certain ellipsoids of elevation,—such, for example, as the Wren's Nest at Dudley, in which the direction of the joints changes with every bend in the external folds of the limestone. Many observations, however, infinitely more than those which are offered in the appendix, are required to solve this problem.

Neither can it perhaps be yet satisfactorily determined, whether the crystalline divisions in the mass were influential in inducing lines of elevation to take given directions; or that the great lines of fissure have simply resulted from volcanic or gaseous efforts, acting in different directions according to the greater or lesser resistance offered by the differently accumulated sediments[1].

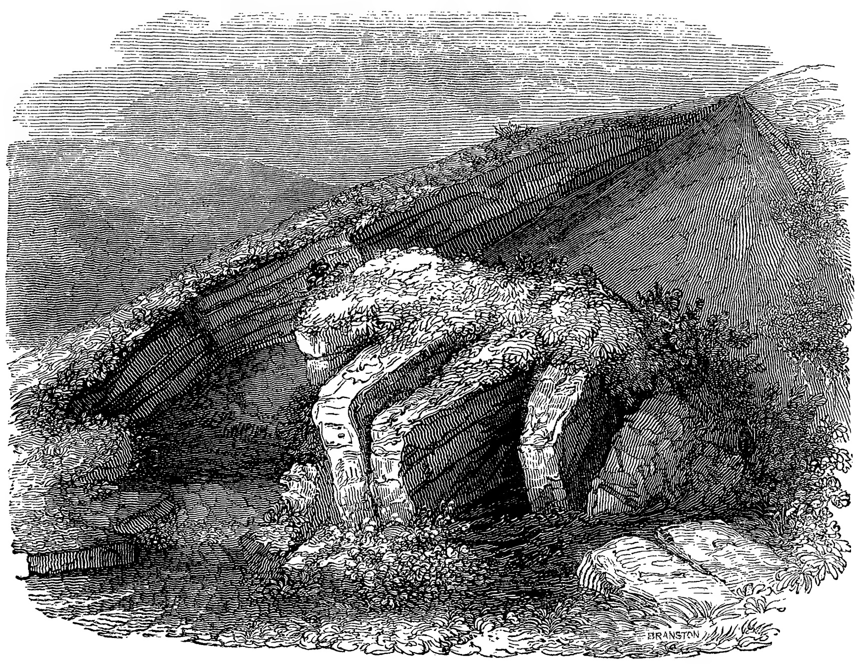
That the crystalline structure was more clearly defined in the more consolidated rock, is evident from the fact, that in soft clay or sandstone (London clay or New Red Sandstone for example) symmetrical joints are rarely if ever discernible; but when masses of similar composition have been *hardened*, whether by heat under pressure, or by pressure alone, they then present neatly defined joints. The phenomenon, as resulting from heat, has been already adverted to in showing how the Caradoc sandstone has been changed into granular quartz rock, and it will be further developed in the description of the Stiper Stones and of the Lower Lickey, &c.

Seeing that strata so altered are more affected by joints in the proximity of the volcanic rock, than at a certain distance from it where they are simply sandstones, and that precisely in proportion as they graduate into an incoherent state the jointed structure disappears, we can I think scarcely avoid inferring, that heat, whether issuing (as in these cases) from an adjacent fissure of eruption, or proceeding on a greater scale from a deeply seated source so as to permeate mountains, has been a prominent agent in the formation of joints. These reflections, as far as my observations go, are applicable to rocks of all ages, and I have merely selected this opportunity to express my opinion, because the formations of the Silurian group expose the phenomena clearly. I shall in future chapters support these views by illustrations drawn from other districts, and in the mean time I refer my readers who cannot travel in Siluria to the illustrative

[1] Professor Phillips supposes "the direction of all lines of disruption to be explicable as a consequence of a general force, applied to masses which in virtue of the *divisional planes previously existing in them,* presented lines and points of least resistance; the result modified by considerations as to the weighting of the strata." (Letter to myself.) Mr. Hopkins, if I mistake not, confines his inquiries to the great fissures or faults produced entirely by dynamical forces, which in elevating large tracts have produced cross fractures, &c.; and though not denying that the jointed structure of many rocks may have been caused by crystalline action, he does not conceive that such a structure could have materially influenced the great lines of dislocation, the direction of which he explains upon mathematical and mechanical principles. (See Cambridge Transactions, vol. vi. p. 1. *et seq.*, 1835.)

wood-cut at the head of this chapter, to that of the Bone Well, p. 250, and to the following view of the landslip at the Palmer's Cairn.

34.




*The Palmer's Cairn, from a drawing by Mr. R. W. Evans.*

## *Landslips of the Silurian Rocks.*

There are some remarkable examples of landslips in the hills west and south-west of Ludlow. As it has been already explained that the rocks in the Ludlow promontory are thrown up on an anticlinal line, and dip away, sometimes at a considerable angle on both sides from a common axis of elevation, it might be supposed, that this sloping position was in itself sufficient to account for masses occasionally sliding down into the lower country. This position alone is, however, inadequate to explain the phenomena[1]. Two other causes have contributed.

1st. The number of joints by which the overlying rocks are divided. 2ndly. The unctuous nature of the surface of the underlying strata.

The most striking landslip in the vicinity of Ludlow is at the Churn bank or "Palmer's

[1] Landslips are in general simply subsidences caused by the shrinkage and wearing away of soft and decomposing materials when overlaid by solid and heavy masses of rock. The south coast of the Isle of Wight abounds in examples of these subsidences, where the pyritous nature of the blue clay, called gault, occasions its disintegration, and hence the overlying rocks of upper green sand slip down and form an undercliff. There are also many similar subsidences at the escarpment of the oolite and lias in the Cotteswold Hills.

Cairn," where large masses of the Aymestry limestone have slid down from the crest of the hill into a comb, exposing the sloping surface of the Lower Ludlow rock over which they have slipped, as explained in the above wood-cut. The area here affected exceeds fifty acres.

The wood-cut exhibits the slope of the beds, and the joints which divide the rock into lozenge-shaped masses: the thin layer of unctuous clay or "Walker's soap" which was spread over the inclined floor of flagstone, facilitated the descent of the disrupted masses.

Of the two causes, the second or jointed condition of the strata has been perhaps the most efficient; and the descent of the masses would doubtless be aided by ordinary atmospheric agents, and perhaps determined by the breaking up of a powerful frost, &c.

The same causes have led to similar slips in other parts of the environs of Ludlow, as on the steep external slope of the ridge called Brindgwood Chace, at a spot called Wheeler Vallet's Wood; while another has occurred in the grounds of Ferney Hall. At the latter place the rocks not being inclined at so high an angle and not impending over so deep a comb as at the Palmer's Cairn, have been slightly moved down the gentle slope, but the joints of the rock have opened out to yawning fissures, extending over a surface of about seven acres. These chasms being now well wooded are very ornamental. On my first visit to the country they appeared inexplicable or were generally supposed to be old stone quarries, and it was not until I had seen the remarkable landslip of Ludlow rocks, in Marcle Hill, (to be described in the chapter on the valley of Woolhope) that I became acquainted with the true causes of the open chasms of Ferney Hall and the great slip of Palmer's Cairn. All these phenomena agree so closely, with slight differences of scenery, that the description of one may serve for all. The slip of Marcle Hill, however, is recorded by our old chroniclers and will be noticed at greater length. Those in the environs of Ludlow may also have occurred in modern times, but from their remote situations or the absence of local historians, the dates of the catastrophes have not been preserved[1].

Besides these greater and more complex landslips of the Ludlow rocks, others of more simple characters occur. One of the most striking cases of this sort happened about fifty years ago on the right bank of the Severn, one mile west of the entrance to Coalbrook Dale, and destroyed a house and barn. This was doubtless occasioned by the disintegration and subsidence of the incoherent shale which here occupies the banks of the Severn. This shale forms the unstable support of heavy overlying masses of the carboniferous rocks; and its partial subsidence is what might very naturally have been expected. Several acres of ground were thrown into a highly varied outline, and now compose little conical hillocks separated by deep hollows, the whole extending in a deltoid form from the side of the hill whence they slipped, to the high road in the valley of the Severn.

[1] Dr. Lloyd, who has proved so good a coadjutor, and who first directed my attention to the fissures at Ferney Hall, has acquainted me that recently, on Mr. Duppa Lloyd's estate at Longville, a large mass of Caradoc Sandstone slid smoothly and rapidly down from its parent seat. The strata are there inclined about 15°, and unctuous clay underlaid the mass affected.

35.

*The Bone Well, from a sketch by Mr. R. W. Evans.*

*Wells in the Silurian Rocks.*

Having explained that the jointed structure of these formations often renders them permeable to water, the natural springs are in such cases to be looked for only at low levels. Thus in Ludlow Castle the artificial well by which the garrison was formerly supplied is sixty-six feet deep, the rock being perforated to nearly the level of the river Teme. The usual sloping position also of the Ludlow rocks, whilst it desiccates the higher parts of the ridges, tends to produce natural springs near the foot of these inclined planes, wherever the strata are affected by faults near the junction of the rock and Old Red Sandstone. At such points also the low country is often loaded with clay, which sustains the descending surface-water and increases the supply, which serves for the well-peopled tracts on the outward slope of the Ludlow formation, and along its junction with the Old Red Sandstone. The faults or dislocations, however, act more particularly as dams to the water and occasion springs. One of the numerous sources due to this cause is the "bone well" near Richard's Castle, about five miles south-west of Ludlow, which has long been a wonder in the minds of the inhabitants. Even in the early part of the 17th century, Drayton thus notices it in his Polyolbion :

> "With strange and sundry tales
> Of all their wondrous things ; and, not the least, of Wales ;
> Of that prodigious spring, (him neighbouring as he past)
> That little *fishes* bones continually doth cast."
>
> London Edition, Folio, 1622. p. 105.

The bones, however, are not those of *fishes*, but principally of *frogs*[1].

A mass of the Upper Ludlow rock, instead of dipping to south-east, or the lower country conformably with the adjoining ridge of Vinnalls Hill, is snapped asunder and plunges to the north. This, like many other dislocations, has given rise to a collection of materials forming a wall or dam, which prevents the descent of water and throws it out to the surface. (See wood-cut.) The water issues from one of the joints before described, and as this joint is doubtlessly connected with many other similar open cracks, which ramify through the higher slopes of the ridge, we can easily comprehend how the minute bones of frogs or even of mice, living and dying on the adjacent hills, should from time to time be washed down through connecting fissures and discharged at the first natural source wide enough to afford them egress; their occasional issue depending on floods, sudden thaws, and such causes[2]. The geologist, indeed, is well aware that lines of fault are often traceable by the outburst of springs alone. We may see a good example of this phenomenon in that denudated part of the Ludlow promontory which constitutes the valley between Yatton Hill and Leinthall Earls, where a land spring is always flowing copiously, the point of issue being precisely upon one of the lines of dislocation previously described.

"The most remarkable springs of this country," says Mr. Lewis of Aymestry in a letter to myself, "are the Lady-pools in Shobden Marshes, the property of Lord Bateman, where the river Pinsley, a tributary of the Lugg, (whose limpid chalk-like stream you were so struck with below the Church of Leominster,) has its origin. They are several in number, within an area of half an acre, varying every day in form and dimensions, from ten to thirty feet across, and fourteen to twenty feet deep. The water is very cold and clear, and fish are seldom observed near its source. The copious supply of water is seen issuing from the bottom by the motion of little confluent cones of fine sand which are continually thrown up, changing their shape, position, and magnitude every moment, the motion suddenly ceasing in one place and commencing in another; a jump, or even a shaking of the ground (bog-land), will stop some of the sources and bring new ones into action; so that the bottom of the pools presents a continually varying aspect, which is really beautiful, and is of course no small cause of wonderment to the country people."

I would attribute these issues (like other land-springs of which I have spoken) to the existence of a longitudinal fault, which ranges from north-east to south-west, parallel to the great line of elevation of the Silurian rocks. Such a fault barring the descent of the waters on the inclined plane of Upper Ludlow Rocks would naturally throw up the water to the surface, and the form of the country favours this view; for the overlying rocks have been denuded, the strata from which the water rises being simply covered by turf or bog.

The shales of the Ludlow and Wenlock formations, when well exposed, are seen in escarpments only, and in that position they can seldom be the seat of natural wells; but whenever they have subsided into undercliffs or mounds, or occur on the sides of denudated valleys, and particularly when covered by gravel or other detritus, they retain the atmospheric waters, and then the wells are necessarily of shallow depth and supplied with good water. In this, however, as in all tracts made

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[1] A small box full of the bones from this well having been examined by that excellent comparative anatomist Mr. Clift, F.R.S., its contents have been pronounced by him to belong exclusively to the *frog*.

[2] I was much indebted to Mr. Jones of Ludlow for collecting bones from this well. In the description of the organic remains I shall further express my obligations to him, in common with Dr. Lloyd and Mr. Lewis, for the donation of many valuable fossils of the Ludlow Rock.

up of dislocated strata, the depth of the wells necessarily varies much within very short distances. Thus at Clungunford, the wells being from four to seven yards deep, are pretty constant, while at Wigmore, in shale of the same age, one source twenty-three yards deep occasionally fails, another twenty-six yards being constant.

### *Mineral Springs.*

The absence of all simple minerals except a very little iron pyrites in the Upper Silurian rocks near Ludlow, renders it improbable that they should contain mineral springs. One, however, is known, the nature of which may be implied from its name the "*Saltmoor* spring." According to a rough analysis of Dr. Lloyd it contains the sulphates of soda and lime, with oxide of iron and sulphuretted hydrogen gas, but the supply of some of these ingredients is very uncertain[1].

Although the bed from which this spring rises is not exposed, there can be no doubt that it is the upper stratum of the Ludlow rock, since that rock is visible at the surface very near this spot, and the well is directly in the prolongation of the edge of the outlier of Tinker's Hill, Caynham Camp, and just where the Ludlow rock subsides beneath the Old Red Sandstone. It has been previously shown that these upper strata occasionally contain sulphuret of iron, from the decomposition of which the contents of the well may in great part be derived; but I would further remark that the spring, like others before-mentioned, is situated upon *one of the lines of dislocation* parallel to the axis of the Ludlow promontory. This fissure, indeed, is a direct prolongation of the great basaltic dyke which penetrates the adjacent coal measures of the Clee Hills. (See Map and p. 126.) In chapters 26 and 27 I shall show that other mineral springs in Radnorshire and Brecknockshire invariably issue from such points of dislocation, particularly where rocks of volcanic origin have burst through, fractured, and altered the sedimentary deposits. The same may be said of the Admaston Spa near the north-western edge of the Wrekin.

### *Agricultural Characters of the Silurian Rocks.*

Viewed as a whole, the Ludlow and Wenlock formations or "Upper Silurian" rocks are so argillaceous, that where not covered by transported materials, their decomposition gives to the surface a distinctive character. Thus no one can fail of being much struck in passing from the Old Red to the Silurian System at the change in the colour, and the diminished richness of the soil belonging to the latter. This observation, however, requires explanation. The Upper Ludlow rock, for example, when composed of an admixture of sand, clay, and lime, may even be termed a good agricultural substratum; witness the produce on the slopes of the rock forming the external faces of the Ludlow promontory, where noble trees[2] are rivalled by excellent crops of barley, oats, and turnips.

[1] I should apologise to Dr. Lloyd for quoting his rough analysis. He observes that this Saltmoor water closely resembles that of Harrowgate in medicinal properties.

[2] The woods of Downton Castle may be specially cited, and the Spanish chestnut trees of Croft Castle are of remarkable size. On the whole, however, the oak timber grown upon the Ludlow rocks is of less value than that of the Old Red Sandstone. As specimens of the latter, see the venerable trees of Oakley Park and the gigantic oak of Nun Nupton near Brimfield.

There is a peculiarity in the soil of the Upper Ludlow rock which might surprise a land surveyor unacquainted with the geological structure of the district; namely, its dryness, or rather the rapidity with which rain is absorbed, a peculiarity seldom if ever observable in soils containing so much clay. I attribute this property to the strata lying near the surface, and being singularly full of joints and fissures[1]. The water having once passed through the thin covering of earth, is rapidly carried off by these deep natural drains; the sloping position of the strata tending also to rapid desiccation.

On the other hand the lower members of the Ludlow and Wenlock formations being soft and argillaceous, and subject to the drainage waters of the upper, are comparatively cold and unmanageable tracts. Yet even this remark is subject to wide exceptions, for in all those situations where the limestones of Aymestry or Wenlock appear at the surface and afford by their disintegration a certain quantity of calcareous matter, its intermixture with the stiff clays forms a soil which yields excellent crops of wheat.

The agricultural character of the Lower Silurian rocks differs much from that of the overlying formations. In this region, where the best types are displayed, the distinction is strongly marked as the observer passes from the valleys of clay or decomposed mudstone to the sloping ridges of Caradoc sandstone. These rocks, being for the most part arenaceous, disintegrate to a sharp soil, not usually very productive, though in those parts where calcareous matter is partially disseminated, a loam of fair quality is the result; and often having a reddish tinge it is not very unlike some of the least productive of the Old Red Sandstone soils. (See p. 193.) Where the quartzose conglomerates or red sandstones prevail the surface is sterile, and striking examples of this may be seen in the Hoar Edge, in the hills of Netherwood, Church Preen, &c., and in the higher parts of the ridges extending from Horderly by Wartle Knoll to Corston near Clungunford.

The soil of the Llandeilo flags is often very good, as might be naturally inferred from the composition of the rock, but as the formation is seldom well developed in Shropshire, (being seen only partially in a region of mines to be described in an ensuing chapter,) its agricultural characters are best studied in Caermarthenshire, on the banks of the Towy near Llandeilo, particularly in the beautiful domains of the Earl of Cawdor and Lord Dynevor.

In the large tracts of North and South Wales occupied by the Silurian System, there are, as before explained, many districts in which calcareous matter is entirely absent, and in such situations, the Upper Silurian rocks being *mudstones*, the quality and nature of the soil may at once be understood. This argillaceous soil, usually of a dark grey colour and sometimes almost black, (forming in many instances what the inhabitants term "rotch" or rotchy land,) is generally cold and of little value (particularly in high mountain tracts), but where it contains a slight proportion of sand and lies upon favourable slopes, it is not unproductive and is specially favourable to the growth of

[1] Notably in the hills above Downton on the rock, Mocktree Hays, &c.

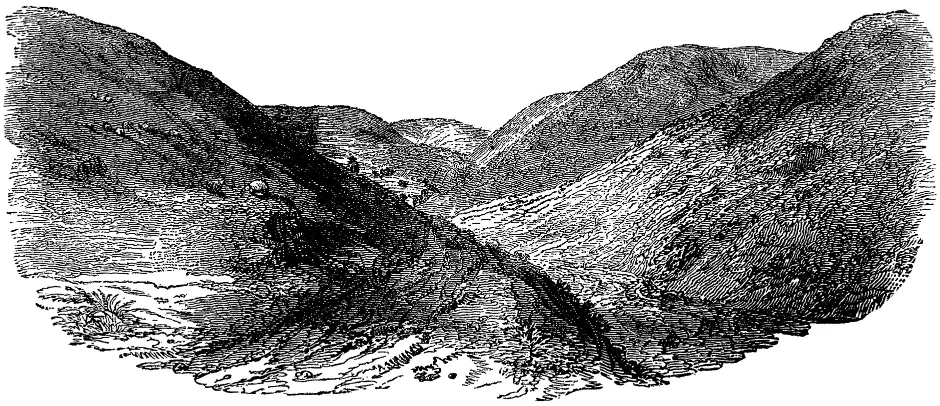
timber. Wherever the sandy or quartzose members of the Lower Silurian rocks rise from beneath this argillaceous cover, a sudden change is observable in the vegetation, a wild heath or poor woodland replacing arable lands or luxuriant woods; but where, on the contrary, the Lower Silurian rocks happen to be calcareous, their points of protrusion from beneath the beds of shale, as at Powis Castle for example, are very fertile. Again, wherever trap rocks emerge, as in the Caradoc, Wrekin, Cornden, or Breidden Hills, still greater diversity in the quality of the land is the result. Some of these varieties will be adverted to hereafter, though in the mean time I would observe that in general the decomposition of the trap rocks of this region is little favourable to vegetation, a circumstance which I attribute to the predominance of felspar[1].

We thus see, that the agricultural features not only vary with each change in the substrata, but are further dependent on joints, dislocations, fissures, &c.; so that it is impossible to offer an opinion applicable to a wide space of country, each district having its own modifications. Among various qualifying causes, none have acted more generally than those operations of water, by which the surface has in many cases been strewed over with gravel and fine loam, in others with boulders and coarse gravel; thus fertilizing some tracts, whilst others have been impoverished. The first of these causes has most frequently operated in valleys adjacent to great rivers; the latter occurs chiefly on mountain sides or slopes. Such phenomena, however, will be described in separate chapters towards the end of this work, and they are now alluded to merely to explain, why many large districts which appear in the map as occupied by particular rocks, have agricultural features very unlike those assigned to such formations[2].

[1] This remark is liable to exceptions, particularly in the spots where the trap contains much carbonate of lime. In general trap rocks decompose to good soils.

[2] I had some intention of rendering this work more interesting to botanical readers by giving (in the Appendix) a list of plants indigenous to the Silurian rocks, but the attempt was abandoned as unconnected with *geological* inquiry. The *mineral* composition of rocks are, it is true, generally indicated by the plants upon their surface; thus it is well known that limestone bears a vegetation very different from that growing upon sandstone or clay; but it matters not whether the limestone be Silurian or chalk; whether the sand be Caradoc or New Red; the clay Wenlock shale or lias. In short, *lithological* structure alone determines the vegetation, whatever may be the *geological* age of the rock. For example, the *Pyrola minor* delights in the Ludlow rocks both near Ludlow and at Abberley, but the same little plant, with its congener *P. uniflora* was first discovered on the primary rocks of the Highlands of Scotland: both have since been found on the carboniferous rocks of the banks of the Tees, and one of them even amid the oolites of Oxfordshire. The beech flourishes on the Silurian limestones and on the chalk, while the Old Red clays of Herefordshire rival, if they do not excel, the Gault and Wealden clays in sturdy oaks.

The *Aconitum Napellus* (common monkshood) has, I believe, been found native *only* on the banks of the Ledwyche brook near Ludlow (Old Red Sandstone). But after all, substratal influence is constantly obliterated by overlying detritus, and it is therefore difficult (except in naked and stony ridges) to trace any connection between the subsoil and the plants.



*View in the Longmynd Hills, looking E.S.E., from a drawing by Mr. T. Webster, F.G.S.*[1]

# CHAPTER XXI.

## CAMBRIAN SYSTEM.

### *PART OF THE UPPER GROUP.*

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*Mineral Axis of Shropshire.—Cambrian and associated Trap Rocks in the Hills of Longmynd, Ratlinghope, Linley, Pontesford, Lyth, and Haughmond.* (Pl. 31. f. 4. Pl. 32. figs. 1, 2 and 4. Pl. 33. f. 1.)

HAVING described the Silurian formations in the district selected as a type, and also the associated rocks of volcanic origin, I now enter upon the consideration of the older sedimentary deposits and the intrusive rocks by which they are intersected.

From their great development in Wales, where throughout a course of one hundred and fifty miles, they either flank unconformably, or rise out regularly from beneath the Silurian strata, Professor Sedgwick has assigned to these rocks the name of Cambrian. This vast system (of infinitely greater thickness than any other in the geological series) is intended by that author to embrace all the older slaty rocks, and has been divided

[1] The above vignette and some other illustrations of this work, including the wood-cuts 24, 26 and 28, are taken from a series of characteristic sketches of this neighbourhood by that able geologist and accomplished artist Mr. Thomas Webster, so long Secretary of the Geological Society of London. The drawings were made in the early days of geology in England, and were intended to illustrate a work on Shropshire (never completed) by Mr. A. Aikin, F.R.S., who liberally placed them at my disposal.

by him into three principal groups. In this work I shall notice the highest of these groups only, particularly where it is contiguous to the Silurian rocks.

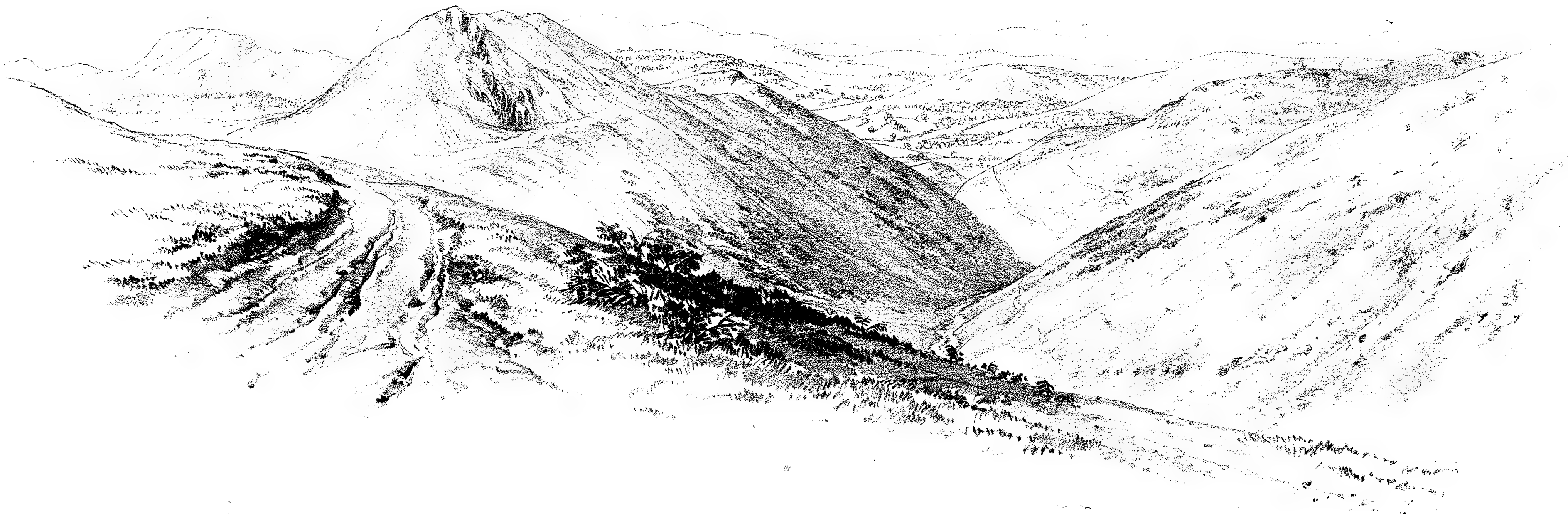
In Shropshire there is no passage from the Cambrian to the Silurian strata, the sequence having been interrupted by the outburst of volcanic matter which formed the Caradoc and Wrekin Hills, as expressed in the sections, Pl. 31. figs. 3 and 4. This eruption, which, as was previously stated, destroyed or obscured all traces of the Llandeilo flags, has also operated in excluding certain transition beds which elsewhere unite the Upper Cambrian with the Lower Silurian Rocks. In this district, in short, there is a great hiatus, for there are natural sections which prove, that the Cambrian group described in this chapter has been thrown into highly inclined positions, before the deposition of certain beds of the Silurian System. (Pl. 32. f. 1.) Not so, however, on the eastern slopes of the Berwyn Mountains, nor in Caermarthenshire; where in place of an abrupt collocation as in Shropshire, there are transitions downwards from the Llandeilo flags, through black schists into the older slaty rocks under consideration. (Pl. 32. f. 9. and Pl. 34. f. 3 and 8.)

In those districts it is obviously impracticable to draw a precise boundary line between the inferior beds of the Silurian and the uppermost strata of the Cambrian System, either by zoological, lithological, or stratigraphical distinctions. As a striking example of this I may state, that the Bala or Berwyn limestone, placed by Sedgwick in the Upper Cambrian group, contains several species of shells, figured in this work as occurring (some of them very abundantly) in the Lower Silurian Rocks[1].

In the meantime, returning to the consideration of the country under review, I shall now give a detailed account of the Cambrian strata with the associated trap rocks, as they appear in the Longmynd and other hilly ranges in Shropshire.

*Longmynd*, &c. Pl. 31. f. 3 and 4. and Pl. 32. f. 1. The Longmynd and contiguous ridges on the west and north-west, comprising the hills of Ratlinghope, Pulverbatch, and Linley, varying in height from 1000 to 1600 feet, consist of a vast succession of strata of hard sandstone, grit, schist, and imperfectly formed slates, which are piled up in mural forms, the beds being either vertical or in very highly inclined positions. The strata constituting these hills have a direction from N.N.E. to S.S.W., and the various ridges are of very unequal lengths. One of the longest is that which is prolonged from the Linley and Pulverbatch Hills into the Lyth Hill, and finally into Haughmond Hill, four miles north-east of Shrewsbury. These Cambrian rocks are flanked on the east and south-east, and south, by the Silurian System and the trap rocks before described. On the west, they are separated from the Lower Silurian Rocks of the mining district of Shelve by a lofty ridge of quartz rock, called the Stiper Stones; and on the north, they are overlaid by the coal measures and New Red Sandstone of the Vale of Shrewsbury, as already explained in the sixth chapter.

[1] The shells which I have collected in the Berwyn Mountain and at Bala, (Upper Cambrian of Sedgwick,) and which are common in the Lower Silurian Rocks, will be enumerated in the twenty-fourth chapter.



Caer Caradoc Brown Clee Titterstone Clee

FROM THE LONGMYND, LOOKING EAST.

T. Webster delt. Day & Haghe lithrs.

Let us first consider the structure of the Longmynd or principal mountain of this group[1].

The stratified rocks of the Longmynd are sandstones, grits, schists, and imperfect slates, of grey and purple colours, in which no traces of organic remains have been detected. Although the outlines of these hills are round and waving, like those of most slaty tracts, the strata are admirably exposed in a number of deep transverse ravines, or as they are here termed "gutters[2]," on ascending any of which the various strata are seen on their sides.

On the eastern flank of the Longmynd or western side of the valley of Church Stretton, we first meet with a zone of black and dark-coloured clay slate of fine texture. This rock is so shattered and splits under the hammer into such cubical fragments that it is with difficulty a fresh fracture is obtained. It is generally very glossy on the surface, very finely laminated, and traversed by a few veins of white quartz and carbonate of lime. It is thrown about at very high angles of inclination, being penetrated by numerous bosses of greenstone, which will be spoken of hereafter. The succession of strata to the west of this clay slate, can be well studied in any of the transverse indentations which diversify the outline of these hills, trending in parallel lines at right angles to the strike. The following account may be taken as a general description of the order in which the strata are exhibited, in crossing their edges from south-south-east to north-north-west.

1. Black clay slate.
2. Greenish compact slate passing into hard, greenish grey, micaceous, slaty sandstone, which breaks into cubical fragments, in beds of two to four inches thick, veined with white quartz.

(Excellent examples of these beds are seen near the mouth of the carding-mill gutter above Church Stretton.)

3. Deep purple-coloured, compact slate, alternating with lightish green, hard, micaceous sandstone. This purple-coloured slate becomes from this point the predominant rock. It is very fine-grained and rarely micaceous.
4. Bluish gray, slaty, micaceous sandstone, alternating with the purple slate.
5. Dull, greenish clay slate passing into a compact rock, approaching to hornstone. There are countless alternations of these beds, and a vast thickness of strata is exposed before we reach the higher grounds where the slates and slaty sandstones pass into
6. Purple-coloured grits and sandstone with nests of crystals of quartz and quartz veins.
7. Thick-bedded, quartzose conglomerates with a base of red and purple sandstone, containing disseminated mica, with fragments and pebbles of grey and white quartz, varying in size from pins-heads to walnuts: some of the pebbles contain cavities filled with chlorite. In other instances they have the appearance of having been altered by heat and indented against each other.

These conglomerates and purple-coloured sandstones constitute the central masses of the Longmynd, and are succeeded on the west by alternations of similar strata (Prolimoor and Wentnor.). They are again followed upon the north-west by various alternations of strata identical with those described, and of which most of the beds of the rivulets between the crest of the ridge and Ratling-

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[1] Most of the Cambrian rocks have a mountain character. The summits of the Longmynd, for example, are covered with heath and tenanted by the red or common grouse. Although it is generally considered that there is no road across these hills, the venerable Earl of Powis, to whom a large portion of the tract belongs, accompanied by Dr. Du Gard, recently passed over them in his carriage, and descended into the valley of Church Stretton by the narrow track represented in the foreground of the sketch, p. 255.

[2] Probably so called from the feeble rivulets which flow in them.

hope afford instructive sections. Still further to the west the purple-coloured grits, sandstones, and slaty schists again prevail, occupying all the hills extending from Linley to Pulverbatch. The red grits (the compound sandstone of Dr. Townson) are evidently of regenerated origin, and often contain many small fragments of older slate in a quartzose cement.

Besides these deposits of obvious mechanical origin, there are in the Longmynd, interpolated strata of slaty felspar rock. These are sometimes so compact as to amount to hornstone; in other cases they are somewhat porphyritic, with flakes of green earth parallel to the lamination. Such rocks might more properly speaking be treated of hereafter among the trap rocks, but it seems impossible to avoid mentioning them, since they are conformably interlaminated with the sandstone and slates. There are, however, also other trappean rocks chiefly greenstone and compact felspar rocks, which as they jut through the inclined edges of the strata in irregular bosses, and exhibit all the marks of having been intruded, will be presently described. (Pl. 32. f. 1.) I have said that on the whole, these ancient stratified rocks have more of the slaty cleavage than any of the overlying deposits. The cleavage planes nevertheless, though marked upon the great scale, are not always clear, consisting rather of a number of minute foliations, which collectively impress upon the rock an ill-defined cleavage. In some of the combs towards the south-eastern end of the Longmynd, there are excellent opportunities to clear up any obscurity respecting the true stratification of the mountain, for we there see lines of true cleavage, and also of joints, traversing the various stratified layers, of entirely dissimilar mineral characters. The line of deposition of these beds is clearly marked by the ends of these stratified masses, each composed of different materials, being exposed on the opposite sides of the "gutters" or combs. It will be shown hereafter, that in this district these great masses of slaty greywacke have undergone powerful movements of elevation anterior to the deposition of the Caradoc sandstones, the two systems being placed in marked unconformability to each other, thus explaining the course of that great break or interval to which allusion has already been made. (Pl. 33. f. 1. and Pl. 32. f. 4.)

The rocks which extend in the narrow ridge from Pulverbatch to Lyth, and Sharpstone Hills, and reappear at Haughmond Hill, near Shrewsbury, are composed of one or more of the strata above described, associated as in the Longmynd and Linley Hills with trap rocks.

### *Trap, altered rocks and veinstones of the upper group of the Cambrian System as seen in the Longmynd and Linley Hills, and their points of prolongation in Pontesford, Lyth, and Haughmond Hills.*

Having stated that the chain of verdant and round-topped hills called the Longmynd, rises to a height of 1600 feet above the sea, that its major axis is nearly parallel to the Caer Caradoc, and that it is chiefly composed of certain slaty rocks and conglomerates of the Cambrian system; I proceed to describe the trap and altered rocks with mineral veins which are associated with these old deposits.

Commencing with the valley of Stretton, we no sooner descend from the flanks of the Caradoc and approach the sides of the Longmynd, than we meet with several outbursts of crystalline greenstone, which cut through the black schist above described. One of the chief masses of this rock is near Dudgley Cottage, about a mile north-east of All Stretton, and immediately to the east of

Shrewsbury road. The dark-coloured schist around this boss of green-stone, and particularly as seen on the sides of the high road, is in an indurated and brittle slate, and breaks into small shivery fragments, with glossy surfaces having a purple plum colour. These altered and vertical strata extend to Church Stretton, where the protrusion of the trap rock and the hardening and fracturing of the schist in contact, are remarkably well displayed at several points; an excellent example occurring near the spot called the World's End, opposite the principal inn.

The greenstone is hard, sometimes compact, sometimes crystalline, and is traversed by veins of carbonate of lime. It rises in round knolls through the schistose beds, upon which it has produced powerful effects; the lamination being obliterated, and many of the thin layers cemented into a mass of so indurated and compact a nature, as to resemble flinty slate. It is also traversed by veins of white quartz and carbonate of lime. This altered mass splits into trapezoidal and cubical forms, of which it is almost impossible to obtain a cross fracture. At twenty or thirty paces from the trap, the schist, though violently contorted, has in some degree recovered its lamination, and upon fracture the rock peels off in layers under the hammer; but we must recede some hundred paces from the intruding rock before the beds entirely recover their natural depositary characters and become the ordinary dark gray schists or clay slate. The whole of the mass of schist around the grounds of the Rectory is more or less altered, and two or three other knolls of crystalline greenstone rise to the surface. In this greenstone are many crystals of iron pyrites. At Brockhurst Castle to the south of Stretton, a thin dyke or course of greenstone has given to that wooded knoll its picturesque form, and the beautifully varied outline of hill and dale in this romantic spot is due to the same cause, the trap rocks and the associated indurated beds of depositary origin occupying the summits, whilst the soft and decomposing shale and schist have been worn into deep dingles.

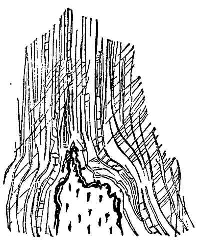
The Longmynd, as before stated, lies to the west of the Stretton Valley, and is watered by several brooks, which descend in the deep "gutters" running from north-west to south-east, and offer transverse sections of all the rocks of which the Longmynd is composed. Two of these merit description, as they develop the structure of the mountain. 1st, The brook which flows to Church Stretton. 2nd, That which waters Little Stretton.

In ascending the former, and entering the region of hard grey and greenish-grey sandstone, we meet with some protuberances of trap, followed by highly altered hard white and green beds, either in vertical positions, or dipping 80° north-west. The trap can be detected at two points. At the first, it is a pinkish amygdaloid, containing kernels of green earth in a base of compact felspar. This is visible only in the bed of the brook, where the bedding of the contiguous slates is entirely obliterated. At the second the trap, close to the amygdaloid, is a dark-coloured, crystalline greenstone. The dislocation of the strata at this spot (above the carding-mill), is very striking, and the rocks have much the character of true slates, being very similar to some of the light green slates on the flanks of Snowdon. The ordinary composition of the slaty sandstone and conglomerate of this mountain has been previously detailed, and I allude to the old slaty aspect of the beds only, because it is principally displayed at points near which the trap rock protrudes.

The defile which traverses the Longmynd from near the summit (where the trigonometrical pole was fixed) to the village of Little Stretton, is, however, by far the most instructive of these natural sections. In this descent, of about two miles, I enumerated upwards of twenty protuberant heads of trap. Some of them are bosses of considerable size; others, mere heads of larger dykes, which rise for a few feet or yards above the stream, and are dovetailed, as it were,

between the vertical and hardened beds of slaty greywacke, amid which they terminate upwards thus,

37.



The trap rocks of the Longmynd, are principally light and dark-coloured greenstone, composed of compact felspar and hornblende; the felspar of some varieties being coloured green by chlorite. White calcareous spar, both in veins and thin flakes, and crystals of iron pyrites are of frequent occurrence. In one of the bosses near the summit of the mountain, the greenstone is highly crystalline, and contains acicular white crystals of common felspar, in a base of pale green, compact felspar. This rock occurs between two feeders of the brook, at about two thirds of the ascent from Little Stretton to the summit, and is the best exhibition of trap in the section, being about 100 feet high, and of forms approaching to columnar. The highest point of rock visible, beneath the thick covering of heather on the summit, is a highly crystalline, dark-coloured greenstone, which juts out from amid purple-coloured sandstone and conglomerate. This spot is about 100 feet beneath the pole placed by the trigonometrical surveyors to mark the highest point. Another variety of trap, observable about midway in this section, is a concretionary rock of dull flesh, and dark green compact felspar, having the mottled aspect of some of the varieties of the Caradoc chain, and passing into a greenstone. At a few hundred paces to the west of the pole cottage, or summit, I met with a large block of rock differing from all those yet described; consisting of separate portions of pink and grey, compact felspar and quartz, in a base of smaller grains of quartz mixed with felspar. At first sight, this rock had all the appearance of one of the conglomerates which abound in this part of the mountain. After all, is it not possible that the included portions of quartz may originally have been pebbles, which being enveloped in a trappean matrix, have been so acted upon by heat, that all the lines of separation between the fragments have been obliterated, and the whole have assumed the characters of a true concretionary rock?

The prevailing strike of the vertical beds which constitute the chief masses of the Longmynd is from north-east to south-west, but this deviation is subject to many partial variations amounting sometimes to 25°. These aberrations seemed to me to be owing to the local protrusions of trap, for on following the strata to some distance from that rock, the north-east and south-west strike was found to be very persistent.

The thin bands of felspar rocks, which alternate regularly with the beds of slate, have been already mentioned (p. 256.). They would seem to belong to that class of contemporaneous trap rocks, of which so many clear examples are adduced in the Silurian System, and though here too ill exhibited to be much insisted upon, they are identical with rocks of that character which occur amid the older slate, and to which allusion has been made (p. 76.).

*Hills of Ratlinghope.*—The western and north-western slopes of the Longmynd consist of the "compound sandstone," schist, and conglomerate, similar to those near the summit, and are here and there intersected by masses of trap. Near the tops of the hills, north of Ratlinghope, some of the latter jut out in hard pinnacles, and are of unquestionable trappean origin, being made up of compact felspar and minute grains of hornblende, but they pass into other rocks, which appear to be the prevailing coarse grits of the mountain in an altered condition with included fragments of indurated purple schist or slate. All traces of stratification are lost in these indurated masses, some of which contain veins and druses lined with crystals of quartz, their surfaces being occasionally coated with *bitumen* or mineral pitch. Besides the rocks of compact felspar, and the associated

altered strata, there are several outbursts of crystalline greenstone, both on the east and west sides of Ratlinghope, similar in composition to some of the varieties described in the eastern slopes of the Longmynd. On the lower side of the hill called Belmont, a fine-grained variety is extensively quarried for building purposes, for which it is better calculated than any of the indurated and intractable slaty sandstones of this district.

The highly inclined and dislocated strata of purple schist and sandstone, which lie between these protruding bosses of trap, are starred through in many directions by veins of white crystallized quartz, which include fragments of the slate and sandstone, the surfaces of the cavities and strings being frequently covered with thin films of grey and green carbonates of copper. These copper veins, commencing to the north of Ratlinghope, are common to the south-south-west as far as Medlicott, where ore has been extracted by the Snailbatch company. Mr. Hawkins, of Ratlinghope, has made trials near that village, but when I visited the spot, he had succeeded in discovering only disseminated coatings and irregular strings of ore.

As similar strings, veins, and nests, containing copper ore, and sometimes accompanied by anthracrite and bitumen, have been found at intervals all along the western side of the Longmynd, even in the similarly composed hills of Lyth near Shrewsbury, it is interesting to detect them also at Ratlinghope and Medlicott, equally associated with and inclosed between rocks of igneous origin.

In fact the whole of the wide tract included between the Longmynd and the Stiper stones, and in which the red and purple slate and sandstones are so predominant, contains at intervals *cupriferous veins with bitumen and other minerals, particularly where there are contiguous intrusions of trap rock*. Thus at Norbury, between the trap rocks of Wentnor on the one side and those of Linley on the other, copper veins are so abundant that they were formerly much worked. In that district, these veins are of high geological interest, for proceeding upwards from the slaty purple rock of these hills they also penetrate the Caradoc sandstone, though the latter rests in *unconformable* and slightly inclined positions upon the former. Thus, near Norbury, the vein containing crystals of sulphate of barytes traverses the limestone beds, loaded with *Pentamerus lævis*, *P. oblongus*, and other Caradoc fossils. No copper veins of more than three or four inches in width fell under my own observation. In one case these veins, though not proceeding upwards, have been discovered to lie beneath the Caradoc sandstone and limestone near Linley, by sinking a spring through those rocks, which gave forth water strongly impregnated with copper[1].

[1] The mineral spring of Prolimoor near Wentnor, to which my attention was first directed by my friend Dr. Du Gard of Shrewsbury, probably rises from altered Cambrian rocks, though it also passes through broken Silurian strata. The surface at this spot is so much encumbered with drifted materials, that no acquaintance with the substrata could have been obtained, had not the Earl of Powis recently endeavoured to improve the spa by clearing away this detritus. I am obliged to Mr. Marston of Aston, who directed this operation, for having furnished me with specimens of the Silurian rock, which I consider to be of the same age as the limestone of Norbury, and I have also to thank him for having detected several points of trap in the adjacent hills. In fact the surrounding strata are so riddled by trap, that I have no doubt this source owes its origin to the intrusion of that rock and the consequent mineral changes in the strata affected, for the limestone alluded to

As the copper veins penetrate equally the slate of the Cambrian System and the overlying Caradoc deposit, it is clear that their formation took place not only after these rocks were consolidated, but also subsequent to those dislocations by which they were thrown into their present relations. Indeed, the evidences in this neighbourhood enable us to go still further, and to infer that the veins were in some way connected with, if not resulting from, the intrusion of igneous rocks among the strata: for not only do we find the strata most veined and charged with ore when they are contiguous to or included between such trap rocks, but we also see that the veins stop where they meet with bosses of the latter, the ores of copper merely lining the adjacent chinks and fissures. I particularly noticed this fact in certain quarries of green, granular, and compact felspar north of the road between Wentnor and Norbury, and where, besides the green and blue carbonates of copper, the cracks were coated with black oxide of iron.

We may now proceed to consider the structure of some of the other trap rocks of this immediate district, or those which have burst out in fissures through the strata of the Cambrian System.

*Norbury and Linley Hills.*—These hills lie between the north-western face of the Longmynd, with which it has been shown they are intimately united, and the remarkable serrated and altered ridge called the "Stiper stones."

The elevation on which the village of Wentnor stands, at the south-western termination of one of the ridges, affords an instructive example of their composition.

In the rugged road which ascends from the Walk Mill (Fuller's Mill) to the Church, the principal mass consists of vertical, contorted, indurated beds of purplish-red sandstone and grit, of the same nature as in the Longmynd; and through their ends rise various wart-like bosses of trap, precisely in the manner described in the Little Stretton Brook. (wood-cut, p. 259.) The trap is a greenstone, in parts concretionary and amygdaloidal, but principally dark-coloured, and made up of compact felspar and hornblende. The shale in contact has occasionally the aspect of Lydian stone, and the sandstone is very hard and sometimes much veined.

Near Gravenor Bridge is a dyke twelve to fourteen paces wide, of dark-coloured crystalline greenstone, containing small concretions of white compact felspar; the sandstone in contact with the trap is indurated. Several other protuberances of more or less finely or coarsely granular greenstone jut out on the sides of Gravenor and Norbury Hills, marking the south-western prolongation of those outbursts, which are to be traced to the north-west on the sides of a small brook as far as the Bridges. On the eastern flank of the Stiper Stones, nearly opposite the centre of the ridge, is a prominent mass of trap, a part of which is called the "Calf Knolls." It is nearly a mile in length

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had coatings of grey copper. (See explanation of the origin of Llandrindod and other mineral sources in the twenty-sixth chapter.)

Dr. Du Gard, who analysed this water many years ago, found the chief ingredients to be the muriates of soda, lime and magnesia, the first in much the greatest abundance; with minute quantities of the carbonates of lime, iron, and magnesia, and a trace of vegetable matter. The proportions of saline contents probably vary in different seasons.

and composed of compact felspar rocks, very like those of the Wrekin and Caradoc, and passes into greenstone. It forms a separate low ridge, divided from the higher quartz rock of the Stiper Stones by a very narrow valley filled with much local angular detritus. I further detected one or two other mounds of trap on the eastern side of the axis of the Stiper Stones near Linley Hall. One of these on the left bank of the brook, is a patch of fine crystalline greenstone. Another is considerably developed on the right bank in the wooded hills called the Knolls, which form a part of the beautiful and diversified grounds of Mr. More. It is an amygdaloid, consisting of kernels of quartz and green earth in a base of dark purple-coloured granular felspar, and passing from granular into compact felspar, with crystals of common felspar and sometimes small grains of iron pyrites. These hills of trap range close up to the quartz rock of the Stiper Stones as prolonged through the Heathmont, and their juxtaposition to these altered rocks, both here and at the Calf Knolls, must be borne in mind when we endeavour to explain in the next chapter the nature of the quartz rock.

This line of altered rock and trap on the east side of the Stiper Stones, or one parallel to it at a very little distance, is traceable along the Habberley Valley to Pontesford Hill and Lyd's Hole.

Between Kinnerton and Habberley the whole line of red and purple sandstone is much contorted, and in parts so veined and indurated, particularly near Gatten Lodge, as to lose all traces of a bedded rock. Where the bedding is discernible it has sometimes an angle of 80°, in other parts vertical, the strike being generally 25° to 30° east of north, but in places north and south. The veins contain carbonate of lime, sulphate of barytes, and traces of the grey and green ores of copper.

*Pontesford Hill.*—In following the line of altered rocks above described to the north-east, and passing by the hollow filled with coarse alluvial detritus in which the village of Habberley stands, we reach the well-known and picturesque hill of Pontesford, which with its associated rocks at Lyd's Hole, forms the chief trappean mass of the district. This hill presents a bold projecting headland towards the vale of Shrewsbury, and from its prominent position, easy access, variety of composition, and beauty of outline, merits a special description. (See the form of this hill in the view, p. 81.)

Nearly all the phenomena of the altered and veined rocks which have been detailed as occurring on the south-western prolongation of this axis are here clearly exhibited, the same appearances being apparent on the sides of Pontesford Hill; and in the narrow gorge by which the Habberley brook finds its exit to the vale of Shrewsbury, particularly on the sides of the rapids and waterfall of Lyd's Hole, we see in actual contact with the concretionary trap, the purple and green sandstones, highly indurated, much veined, in parts brecciated, and almost approaching to coarse jasper. Thin films of steatitic matter or serpentine occasionally line the faces of altered rock, and the mica of the sandstone has disappeared. Receding only a few hundred paces from these dykes and shoulders of the Pontesford Hill, the sandstone, shale, and conglomerate, though in vertical or highly inclined beds, have regained their usual characters, as may be seen in the Oaks Wood, Plealy Banks, &c.

Other veined and altered rocks adhere to the north-eastern face of Pontesford Hill; and numerous trials have been made in search of ores, which, though found in small nests and veins, have

never repaid the speculators. Similar adventures have been made amid the disturbed strata below Lyd's Hole and with no greater success.

The central mass of Pontesford Hill is composed of trap rocks, which rise in a double bossed outline to the height of 950 feet above the sea. The summit consists chiefly of a fine-grained crystalline dark-coloured greenstone, with occasionally small grains of steatite and some quartz finely disseminated. Near the south-west end of the hill and above the village of Habberley the rock passes into a beautiful amygdaloid, having a base of dark purple compact felspar, and kernels of calcareous spar and green earth. There are other varieties of this amygdaloid, which in the opposite side of the hill pass into a grey porphyry. Some of the amygdaloids contain concretions of quartz as large as hens' eggs. A common variety of the trap is a deep purple compact felspar, with much lime both disseminated and in strings.

The dykes of trap laid bare in the contiguous chasm of Lyd's Hole, and which have produced the alterations in the sedimentary rocks above described, are as follows:

1. Small concretionary dark purple felspar with veins of carbonate of lime, occasionally coated by films of steatite or serpentine: the concretionary structure being sometimes lost it passes into a simple felspar rock.
2. Dark purple and white amygdaloid, the base charged with iron and a little disseminated lime.
3. Pale green compact felspar rock, here and there inclosing small portions of schist.

### *Trap of Lyth Hill, Sharpstone Hill, and Haughmond Hill, near Shrewsbury.*

Other parallel lines of trap, having a true south-westerly and north-easterly direction, in conformity with the strike of the elevated strata of the slates and sandstone of the Cambrian System, are observable at various points from the southern end of Lyth Hill to Bayston or Sharpstone Hill near Shrewsbury.

At Stapleton Alms House is a dyke of coarse-grained crystalline greenstone, which throws off vertical beds of purplish grit and sandstone; and a similar rock is quarried on the south-western face of Lyth Hill, near the spot where it rises in a conical form through the same sandstones and grits, which at the point of contact with the trap are veined and contain druses coated with anthracite and calcareous spar. Some of this anthracite is in a viscid state and runs out from the cavities in the state of mineral pitch; other portions are completely charred, resembling cinders. We shall presently point out a much more remarkable instance of this phenomenon in similar rock at Haughmond Hill. Traces of copper ore have also been detected.

In Bayston or Sharpstone Hill the trap forms small dykes, irregularly parallel to the strike of the vertical beds of sandstone, schist, and conglomerate. It is there a greenstone both coarse and fine-grained, being for the most part in a decomposing state; with it is a conglomerate made up of pebbles of quartz and indurated clay, with a base apparently similar to that of the trap.

Beyond these low hills, about two and a half miles south of Shrewsbury, is a depression in the prolongation of the Cambrian strata (the valley of the Severn), which is filled up with patches of the coal measures at Sutton and Uffington overlaid and surrounded by much of the Lower New Red Sandstone. (See p. 81 *et seq.*, with view.)

*Haughmond Hill.*—This hill, rising from the low country of red sandstone and carboniferous strata as represented in the left hand of the view p. 81, is composed, like the

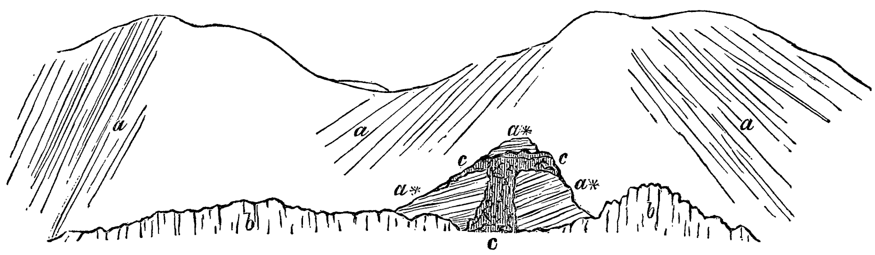
Longmynd, of conglomerate, slaty sandstone and schist. It is cut through on its south-eastern side (the Warren) by syenitic trap and greenstone, composed principally of flesh-coloured felspar with some hornblende and quartz. The schist and sandstone near the flanks of the trap are in vertical beds, striking due north-east and south-west.

At Ebury Wood, the northern termination of this elevation, another boss of trap has been laid bare by clearing away the surrounding strata of altered and indurated strata. It appears that the trap at this spot, protruding in a dome-like or sub-conical form, has thrown off the slate and purple sandstone on all sides. These strata are very brittle, and break into prismatic fragments. Their faces are sometimes coated with serpentine and films of anthracite. The trap is grey, granular felspar, with very fine acicular crystals of common felspar and a little disseminated carbonate of lime. It passes into a sandy-looking granular rock with small crystals of felspar and grains of quartz.

In ascending the hill from Downton and proceeding to the north-east we find the slaty rocks in nearly vertical positions, and on reaching the summit of the "Warren" they give way to and are entirely cut out by a large mass of trap, which there protrudes in rugged lumps from ten to twelve feet above the turf. This mass is composed of syenite and syenitic greenstone, as above mentioned, and is about a quarter of a mile wide. To the north-east it sinks beneath indurated siliceous sandstones, passing into quartz rock, in the same manner as on the sides of the Wrekin and Caradoc. This line of eruption is parallel to that of Ebury, and although the trap is not visible upon the surface beyond the Warren, the linear direction of the outburst is marked for a mile to the north-east by a zone of dislocated and altered rocks, the last of which is seen near the four cross roads between Haughmond and Ercal. The highly indurated and apparently altered strata which appear in various parts of Haughmond Hill, whether at the ascent near the Abbey or at the Criftin, are all indicative of changes similar to those described in chapter 18. at the Wrekin, Charlton, &c.

The most remarkable appearance connected with the trap of Haughmond Hill is at Downton, its south-eastern extremity. At a small knoll near the farm-house, the beds of slaty sandstone are thrown off in opposite directions, as at Ebury, from an underlying irregular protuberance of felspathic trap, which has been quarried down below the ordinary surface of the adjacent ground, as rudely expressed in this wood-cut.

38.




*a*. Slaty schist and flagstone (Cambrian) forming the mass of Haughmond Hill. *a**. The same resting upon trap, has been cleared away from the underlying trap on the sides. *b*. Trap rising in irregular bosses, the schist in contact highly altered. *c*. Vein proceeding from the floor of trap, filled with bitumen and fragments of schist, &c.

The mass of the slaty rock near the trap (*a**) is very brittle and fractures into small rhombs, externally dull blue, but of a greenish grey colour within. A few small flakes of anthracite appear here and there with veins and nests of white quartz. At one point above the nucleus of trap the quarrymen exposed and left standing (when I was last there) a conical mass of slaty schist about twenty feet high, a great portion of the surfaces of which was covered by bitumen, which had exuded from the interstices and oozed over the inclined edges of the rock. On examining this mass more attentively, I observed that the bitumen was supplied from a vertical vein or fissure, the greatest width of which was about two and a half feet, and which proceeding upwards from the trap terminated in a narrow channel, whence the viscid matter flowed over upon the sides of the slaty rock, sometimes covering it in globular forms, sometimes in black lines and films. The vein from which the bitumen exudes, consists of fragments of the sandy slate itself, which are frequently cemented by the bitumen. The immediate contiguity of the trap to the slaty rock is a most interesting discovery, and leads very naturally to the belief that the same volcanic action which produced the trap may have produced the bitumen, whilst it also explains the origin of similar phenomena in Lyth Hill, the Longmynd, and other places in this district. The bituminous matter thus occurring so frequently at points where trap rocks are intruded amid the strata, might at first sight appear to support the theory of Breislack, who observing the abundance of petroleum in the neighbourhood of volcanos, and the quantity given out during their eruption, conceived that all volcanic operations might be due to the ignition of that combustible in subterranean caverns, set on fire by the action of some third substance, such as decomposing sulphuret of iron[1]. This hypothesis has not, however, been favourably received by geologists, who consider such a cause to be quite incommensurate with the great effects produced by igneous action. Without, however, entering further upon the question of the source of volcanos, the frequent occurrence of mineral pitch in these ancient rocks is undeniably a valuable link, in establishing the parallel between their composition and those of modern volcanos, disposing us still more to adhere to the belief of their common origin.

As Lilleshall Hill is the extreme prolongation of the trappean line on the eastern boundary, so is this of Haughmond Hill the last evidence on the left bank of the Severn of the continuance of this western parallel. Both these hills of trap rock are surrounded by the New Red Sandstone, the strata of which rest in positions more or less horizontal upon the vertical or highly inclined edges of the older slaty rocks, and have evidently been deposited subsequent to these trappean eruptions. In a subsequent chapter, however, it will be shown that other trap rocks (on the axis of the Breidden Hills) have cut through the New Red Sandstone.

In respect to the course of these ridges of trap rock in Shropshire, we have to remark

[1] See Daubeny on Volcanos, p. 357.


CORNDEN HILLS, FROM THE SOUTH.

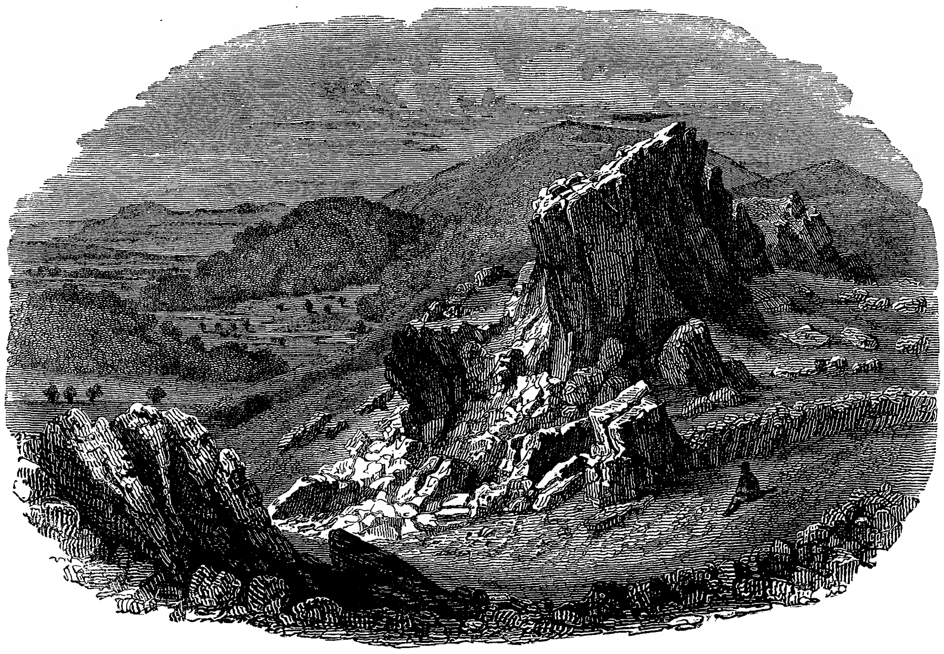
*T. Webster del.*

*Day & Haghe Zinc.*

striking *deviations from parallelism*, even in those cases in which the strata affected *are of the same age*, and on the other hand, *coincidences of parallelism* between rocks formed at *different epochs*. For example, in Haughmond and Lyth Hills, where the sedimentary deposits affected are the Upper Cambrian or oldest treated of in this work, the strike is from north-east to south-west, or parallel to the axis of the Silurian Rocks, whilst near Pontesford Hill, where the strata are mere continuations of those of Lyth and Haughmond and throughout the Longmynd and Linley Hills[1], the strike is N.N.E. and S.S.W.; being a variation of 25° in the direction of the same beds in a distance of a few miles. A similar direction to the N.N.E. is observed in the Lower Silurian rocks of the mining region of Shelve and Corndon, whilst in the Breidden Hills, the strata being of the same age, the strike is E.N.E. and W.S.W., making a diversity of 50° between two *contiguous* lines of eruption. (See the Map.) In all these cases the strata belong to the Cambrian and Silurian Systems, and some of the youngest members of the latter are by reversed dips and renewed anticlinal lines repeatedly brought to day far to the westward of their principal line of bearing in Salop, Hereford, Radnor, Brecknock, and Caermarthen, as will be explained in the following chapters.

The stratified rocks described in this chapter (Longmynd, &c.) are lithologically similar to, and probably of the same geological age as the so-called greywacke of the Lammermuir and other hills in the south of Scotland. They may also be placed in parallel with much of the greywacke of the north of Ireland, and with that of large tracts in Somerset and Devon.

[1] The strike of the Longmynd (N.N.E. and S.S.W.) is parallel to that of the Cambrian Rocks of North Wales.



*View from the south end of the Stiper Stones by the Rev. J. Parker of Sweeny.*

# CHAPTER XXII.

## LOWER SILURIAN AND TRAP ROCKS (*resumed*).

*Lower Silurian Rocks alternating with Volcanic Grits* (Shelve &c.).—*Amorphous or Intrusive Trap* (Corndon, &c.).—*Altered Rocks and Veins of Lead.*—*Quartz rock of the Stiper Stones.* (Pl. 32. figs. 1, 2 and 3.)

THE lofty and rugged tract around the village of Shelve, including the adjacent parts of Salop and Montgomery, is of high interest to the geologist, as it offers the clearest evidences of having been the scene of long-continued igneous action, renewed at distinct and successive periods; whilst the position of the valuable metalliferous veins with which it abounds, affords strong reasons for believing that they are due to causes connected with the intrusion of volcanic rocks.

The chief mountain, the Corndon (1550 feet above the sea), occupies the central ridge, which extends to the Grimmer rocks near Minsterley on the N.N.E., and to Symmond's Castle, a projection from Todlethir or Taudley Hill, on the S.S.W. This central mass, consisting for the most part of trap rock of intrusive character, is about

seven miles long and is flanked on both sides by smaller parallel ridges of hard trap, alternating with valleys formed in the shale and sandstone of the Lower Silurian rocks; the trap occupying the crests, and the softer parts of the sedimentary deposits the water-worn depressions[1].

In the low country which surrounds this tract on three sides, the Stiper Stones forming the fourth, are the villages of Minsterly, Worthen, Chirbury, Church Stoke, Snead, and Lydham. Although this circumjacent country is composed essentially of Silurian rocks, it is succeeded at a very short distance to the north by the coal-field of Pontesbury. (See pp. 81 *et seq.*) On the west the depression, in which is Morton Pool, is occupied by the lower part of the Upper Silurian rocks, which rise into the Long Mountain, 1330 feet above the sea. (Pl. 32. figs. 1, 2 and 3.) The map and annexed sections must be consulted to render intelligible the true nature of this district, since any descriptions would fail sufficiently to explain its complicated structure.

This tract, like others hereafter to be noticed, contains two classes of trap or submarine volcanic rock, i. e. *bedded* and *unbedded*, each of which is divisible into several varieties. The bedded trap rocks frequently alternate conformably with sandstones and flags containing organic remains; whilst the amorphous and unbedded trap rises abruptly, cutting through and generally dislocating the strata. In some instances, however, these two classes seem to pass into each other. (See p. 277.)

### "*Volcanic Grits.*"

The stratified trap rocks occur at intervals on both flanks of the Corndon or principal eruptive chain, alternating with regular sedimentary deposits. We proceed therefore to point out first a few cases of such alternations, as they are older than the intruded trap. In traversing the various parallel ridges between Wotherton and Marrington Dingle, till we reach the flanks of the chief mountain, the following succession of rocks is met with. (Pl. 32. f. 1.)

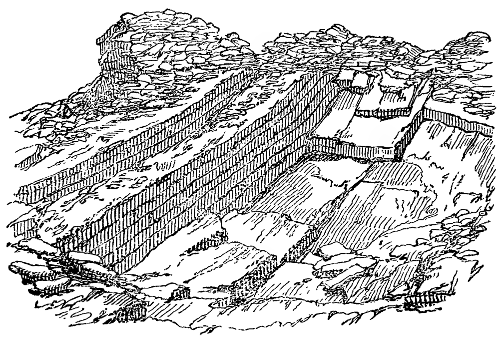
1st. Beds of schist and sandstone (Chirbury and west side of Marrington Dingle). 2nd. Thick-bedded, mottled, felspathic sandstones, dipping 45° beneath No. 1, and largely quarried along the eastern slopes of that gorge (Whittery quarries). The upper beds, from one to two feet thick, are distinctly quartzose and felspathic, sometimes, though very rarely, containing casts of shells, and are separated by courses of dark-coloured shale. Below these are beds, from three to four feet thick, of mottled *freestone*, consisting of a light greenish grey, granular felspar, mixed with some sand, occasionally coloured dark-green by chlorite, and entangling angular fragments of greywacke schist as well as porphyritic greenstone. 3rd. The excellent building material, No. 2., passes down into a concretionary felspar rock, sometimes porphyritic.

This view of one of the Whittery quarries conveys a clear idea of the arrangement of such vol-

[1] This outline of high ridges and deep furrows necessarily impedes the passage *across* the district, and no effort was made before the year 1834 to open it out to the public by the obvious method of constructing a road from north-north-east to south-south-west in one of the longitudinal valleys. This road, which was not commenced till nearly four years after my first visit, is now completed, and is already noticed in a beautiful quarter sheet of the Ordnance Survey just published. Taking advantage of the longitudinal depressions, this road, ascending from Minsterly by Hope Mill, passes in the hollow between Oakage and the Nick Knolls (see Pl. 32. f. 1.) to the Grit Mines, whence it descends by the east and south of the village of Hyssington to the vale of Bishop's Castle near Church Stoke. A direct communication is thus opened between Shrewsbury, Montgomery, and Newtown.

canic grits and breccias, their conchoidal fracture when first extracted being apparent in the loose blocks of the foreground[1].

40.



*From a drawing of Mr. T. Webster, F.G.S.*

Passing from Marrington Dingle to the east or south-east, we meet with the following alternations of rock:

4th. Flags and shale. 5th. Stratified trap, breccia and grit, of which more will be said in describing other parts of the district. 6th. Various alternations of shale and trap-tuf, which extend to one of the longitudinal furrows or denudations, the surface of which is covered by yellow clay.

All these masses, except the last, are *conformably* inter-stratified, and overlie a system of black flags, containing at Marrington and Middleton the *Asaphus Buchii* and other trilobites. A parallel zone of trap runs from the Lower House by Kinton to Wilmington, a distance of more than two miles, and although clearly of intrusive character it may be here described to complete this section. Between Rorington and Wotherton a quarry in this band shows it to be there thirty feet wide. The upper and lower surfaces of the trap are precisely parallel to the beds of schist and sandstone dipping 60° north-north-west; the trap itself not being divided into beds, but arranged in masses more or less prismatic. It is an amygdaloidal greenstone in a decomposing state, the kernels, about the size of a bean, consisting of calcareous spar and a few crystals of iron pyrites disseminated through the mass. On following its strike to the north-north-east this band reappears at Wilmington, where it has about the same thickness. Here, however, the mass is not decomposed, and contains kernels of crystallized olivine and calcareous spar. In this, as in the former case, the sides are parallel to the inclined strata, the trap arranging itself into four and five-sided columnar forms, the ends of the prims being at right angles to the walls of sandy schist as expressed in the wood-cut 44, p. 275. At a few paces distant from and overlying the dyke I found specimens of *Asaphi*, the beds containing them dipping to the west-north-west.

Transverse sections to the flanks of Stapely Hill, by Middleton, Rorington, or Meadowtown, exhibit the black flags, with *Asaphus Buchii* and other species, rising from beneath all this system of shale, sandstone, and trap, in the following order:

8th. Black shale and true Llandeilo flags loaded with both the species of trilobite, viz. *Asaphus Buchii* and *A. tyrannus*, so common in Caermarthenshire. 9th. Stratified felspar rock, almost compact. 10th. Volcanic grit and sandstone of dingy green colour, passing downwards into felspar flags, with many fragments of trilobites. 11th. The same greenish grey flags, but of a more crystalline aspect, composed of grains of felspar, quartz, and hornblende. These also abound in casts of trilobites, the surfaces of the beds being also marked by branching bodies, fucoids? 12th. Black shale and sandstone.

In the whole of this series, as exhibited on the sides of a ravine, the strata are perfectly conform-

[1] This stone is now coming extensively into use for building and is of excellent quality.

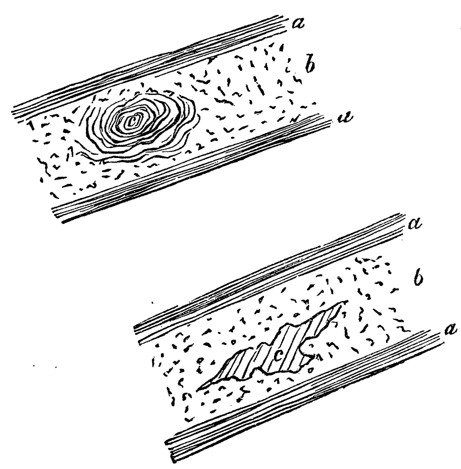
able, dipping to the west-north-west at angles of 40° and 45°. The junction with the amorphous and massive trap of the Llanfawr and Corndon is obscured in the slope of the hills.

If another transverse section be made across the ridges and furrows of the hilly tract to the south-east of Leigh Hall, we perceive other alternations of trap and shale. We here, however, find the stratified masses thrown over in great undulations both to the west-north-west and east-south-east. (Pl. 32. f. 2.) The first of these, lying to the east of Leigh Hall, is a very remarkable rock. It is a hard grey, regularly bedded, compact felspar, in parts porphyritic, containing fragments of indurated schist, and passes into a rock undistinguishable from some of the concretionary traps. Calcareous matter enters largely into its composition, frequently appearing in small crystals. It contains also a small *Euomphalus* of undescribed species and other shells. (See *Euomphalus Corndensis,* Pl. 18. f. 16.)

Notwithstanding the regular bedding of this rock, in layers varying from eight inches to two feet thick, and the occurrence of organic remains, I am convinced that like the strata at Middleton and Marrington Dingle, it is of volcanic origin and formed of matter thrown down from submarine outbursts, mixed with the usual exuviæ and sediments of the ocean. (See section, below the large map, indicating the method by which such rocks were formed.)

In the Notmoor and Lordstone Hills, on the anticlinal line of the Corndon, beds of the same nature as at Leigh Hall, dip in a reversed direction. (Pl. 32. f. 2.) On the summit of this ridge are lines of regularly bedded concretionary trap, the upper and lower faces of the strata being quite conformable to ordinary bedded masses of the shale and flagstone with which they alternate. In hand specimens much of this trap might, without the aid of the lens, be mistaken for a common grit, but it really consists of concretions of compact felspar, and contains crystals of common felspar, hornblende, and iron pyrites, with a little disseminated lime. The beds dip 25° to the east-south-east, and are from two to three feet thick, splitting into flags. At Bromlow Callows, in the prolongation of these stratified masses to the south-south-west, there are many other varieties. (see Pl. 32. f. 2.) They consist of compact felspar with concretions of felspar, some very minute, others as large as gourds, together with grey granular felspar, and finely laminated volcanic sandstone. These and other trap rocks, in beds from two to ten feet thick, alternate *many times* with shale. In parts the trap is somewhat of a breccia, enveloping fragments of schist, in others it is coiled round lumps of schist in concentric folds thus, the laminæ of the schist following the form of the nucleus; but in this as in all other examples the bedding is distinctly preserved, the dip being 45° to the east. *a*. Schist and flagstone. *b*. Volcanic grit, enveloping fragments of schist (*c*). In a second quarry at Bromlow Callows, some beds of the volcanic breccia pass into grit, others are complete greenstone slates; in a third are cream-coloured claystones, with concretions of compact felspar alternating with micaceous sandstone. The harder sandstone and schist are generally much fractured by vertical joints ranging north to south. The section being prolonged from Bromlow Callows to the east-south-east, (Pl. 32. f. 2.) passes over another low parallel ridge, called Oakage, the strata of which are reversed, dipping 40° to the west-north-west. In this ridge is much porcellanite.

41.



Transverse sections at the southern end of this district, i. e. from the Linley Hills to Taudley, passing near Hyssington, expose similar repetitions of bedded trap, sometimes forming distinct ledges, which alternate with shale and sandstone, altered and unaltered. In these ridges and furrows the dip of one range of high ground being to the west, that of the next is usually to the east, and generally at angles of 40°; so that by anticlinal and synclinal lines there is a folding over and repetition of the same strata as in the Lordstone and Callows Hills, dependent doubtless upon parallel lines of eruption. (Pl. 32. f. 3.) These ridges are prolonged to the north-north-west into low hills upon the sides of the road near Grimmer, between Minsterly and Leigh Hall, where they subside, together with certain bosses of amorphous trap which appear upon their flanks. At Hyssington Common, near the other extremity of the chain, the lowest visible masses dip to the east, and consist of thick and thin beds of light-coloured, felspathic conglomerate, occasionally containing crystals of common felspar, but here and there becoming coarse with entangled fragments of schist. These are overlaid, on the dip, by hard, dark grey or blue, felspathic amygdaloid, in parts assuming a columnar structure. Though bedded on a large scale, this rock seems to have somewhat an irregular direction, and to throw off the strata in a highly altered condition, including thin courses of white china stone, nearly resembling the porcellanite of Whitsborn Hill. (See p. 275.) In following these courses of altered rock, trap, and shale, to the old castle of Hyssington, the dip increases from 45° to 70° and 80°; but amid much contortion the strike is preserved to the north-north-east. Between Hyssington and Hurdley, (on the flank of Taudley) the dip of the strata is again completely reversed, and they are inclined to the west-north-west[1]. In Sunny Bank is an outburst of trap rock wholly unbedded, which is prolonged in low knolls to the east of Hurdley, throwing off the strata sharply to the west. This felspar rock, both granular and compact, has a conchoidal fracture and rude columnar form, and is fissured by many rents and cracks; it is in parts amygdaloidal, with nests of green earth and crystals of felspar, and has been extensively quarried as a coarse building stone. On the west this intrusive rock is again flanked by schists, which are overlaid by thick and thin beds of the hard felspathic agglomerate, with fragments of schist, containing many crystals of iron pyrites. These massive trap beds, which are also much quarried as road stones, dip 60° west, and are overlaid by slaty porphyry and grey granular felspar rocks, and highly indurated schists, alternating in courses *a few inches thick each*. In Brith-dir to the north of Hurdley, and on the flank of Roundtain, similar examples of alternation of trap and shale (the prolongation of the same beds) are exhibited on a large scale. The trap is for the most part a mottled felspar rock, with crystals of common felspar and nests of decomposed iron pyrites. It is worthy of remark, that the strike of these linear masses from Brith-dir to Hurdley, or those on the eastern side of Roundtain and Taudley, is very nearly north and south; and those upon the western flank of those hills due north and south, being a difference of 25° from the direction of all the other prominent ridges of the district. This diversity or apparent folding round near the end of the chain, seems to indicate, that the sediments have been thus arranged round the great centre of eruption of this volcanized tract, dipping away from it on all sides.

A great many examples have been cited of the intimate manner in which the stratified trap of this district alternates with the ordinary sedimentary deposits, to convince the reader that such dejections must have taken place *during* the formation of those Lower Silurian rocks with which the volcanic matter is interstratified. I would only further add that these bedded trap rocks so completely assume the features predominant

[1] The black shale at Llanerst contains trilobites.

in all strata which have been equably deposited and *symmetrically* consolidated, that no doubt can remain as to the nature of their origin. In these we find numerous joints, diagonal, transverse, and longitudinal, having as precise relations to the planes of the beds as any joints in sandstone, limestone, or shale; their course changing uniformly with every variation in the strike and inclination of the strata. This point of coincidence between the bedded trap rocks and the ordinary accumulations of sediment is the more essential to keep in view, because the same symmetry is not observable in the intrusive trap rocks[1].

### "*Chief masses of Eruptive or Amorphous Trap.—Altered Rocks, &c.*"

We now pass to the consideration of the principal masses of unbedded or eruptive trap, which have dislocated at various points the sedimentary deposits and volcanic grits, and thrown them into anticlinal and synclinal lines.

The structure of the chief mountain (Corndon) is best seen in its east and south-eastern flanks in bold and rugged escarpments, large subsided masses of which encumber the sides of the Hyssington Marsh. The rock is chiefly a coarse-grained amorphous greenstone, of equal parts of compact, light-coloured felspar and dark hornblende, with small crystals of iron pyrites; but in parts it passes into a finely granular basaltic rock.

If this be considered the principal axis of this convulsed region, we find that on both sides of it there are other courses of eruption, producing parallel anticlinal lines of greater or less longitudinal extension. Any transverse section from the western or north-western flanks of the district to the Stiper Stones would pass over these separate anticlinal lines, the strata on each side having reversed dips. These lines are in general directly upon the prolongation of *short* ridges of intrusive trap. (See sections, Pl. 32. figs. 1, 2 and 3.)

A transverse section from the neighbourhood of Woferton, Marton, or Wilmington, to any point along the chief axis, not only exhibits a succession of fossiliferous strata as before described with much volcanic grit, but also with unconformable protruded trap. Some of the most prominent of the exterior elevations of trap occupy the "ridge," extending from the flanks of Marrington Dingle to the north-east, through the Black Knolls to the Crest Hills. (Pl. 32. f. 1.) This ridge has a length of about three and a half miles, and an average breadth of a quarter to half a mile, except at the spot called the "Black Knolls," where various small promontories of trap give it a width of nearly one mile. Within this space the trap protrudes at many parts through the shale. At Wotherton quarries (the westerly end of the trap) the nucleus of the hill is concretionary felspar, passing into a greenstone *c*, which on two sides graduates into bedded felspar *b* and on a third throws off shale *a* in dislocated forms, containing a vein of sulphate of barytes thirty feet wide *d*, from which the mineral is extracted for use.

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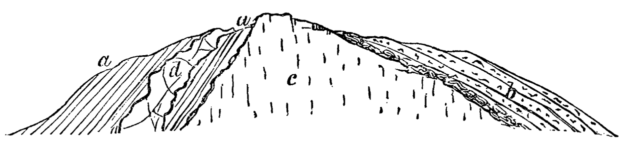
[1] See chapter 20, in which the subject of jointed structure is considered.

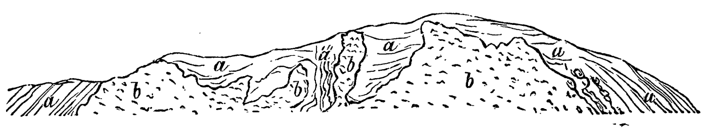



42.

In the Crest Hill and Black Knolls are the following varieties of trap :

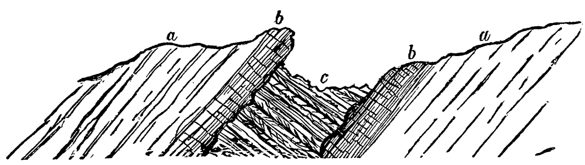
1. Compact felspar rock. 2. Do. porphyritic. 3. Do. porphyritic and concretionary, with grains of hornblende, crystals of common felspar, and iron pyrites.

Near the Crest Hill some of the traps exhibit clear proof of having been intruded into the shale posterior to its consolidation, particularly in the ascent from Wotherton, where a porphyritic felspar rock *b* bursts up through shale *a* containing *graptolites,* in the singularly irregular forms exhibited in this diagram.



43.

This shale could not originally have been deposited in its present highly contorted and broken form : but the peculiarity of the intrusion consists in this, that although the shale is much fractured yet it is wholly what geologists would call *un*altered, being as soft and thinly laminated as if the layers were in their original position. Here, therefore, where from the condition of the beds of schist, and the irregular forms of the trap, there can remain no doubt as to the latter having been forcibly intruded, we see that circumstances which we are unable to explain have prevented the induration of the schistose strata so common in similar cases. Another line of trap, which must have aided in elevating the ridge of Meadow town, terminates near Leigh Hall, and is instructively exposed in the centre of Whitsborn Hill, (Pl. 32. fig. 2.) at the north north-eastern end of which it is largely quarried as a road stone.




44.

The trap has a maximum width of forty feet, but diminishes in parts to about twenty-four feet, and is arranged in irregular columnar masses *c,* the ends of which are, as in the Kinton dyke, at right angles to the highly inclined beds of schist *d.* These beds lie immediately on the western side of the great axis of the Corndon, of which Whitsborn Hill is one of the north-north-eastern spurs. The trap consists, for the most part, of a dark greenstone, made up of felspar and hornblende, with veins and flakes of white carbonate of lime, with thin films of asbestus, and crystals of iron pyrites. This passes in the centre into a fine, hard greenstone, which, although without veins, contains carbonate of lime minutely disseminated. Another variety is a grey felspar, of a rough fracture, whilst the exterior of the band is in parts a grey porphyritic compact felspar. These varieties show that even in a mass of this size, it is difficult to assign any *one* descriptive name to the rock. We may safely term this a dyke, although I am disinclined to use that term without explaining that the

trap does not traverse or cut through the adjacent strata, but ranges parallel to their direction. It is not, however, conformably interstratified, but presents an irregular surface and wedge-like form; and further, the mass is not divided into beds divided by joints, but is made up of columnar forms, terminating abruptly against the sedimentary deposits, which, to complete the proof of intrusion of the trap, are highly altered on both sides of it. This dyke is interesting in presenting an example of the alteration of the schists in contact *b*. Specimens of the porphyritic felspar can be detached with portions of schist adhering to their exterior, almost silicified, some being dark, but passing into a whitish cream, compact clay-stone, resembling porcelain.

It is arranged in fine laminæ in all two or three inches thick, the lamination being occasionally marked by lines of white calcareous spar. This band has a conchoidal fracture, and a surface as smooth as the finest lithographic stone.

It is in fact the "brand erde" or burnt earth of the Germans, a substance which we know has been formed by the combustion of beds of lignite and coal, producing a long continued heat, which has acted upon the associated shale. In England the most curious actual illustrations of this process are in the South Staffordshire coal-field, particularly in the western suburbs of the town of Dudley, where the spontaneous and long continued combustion of coal in the abandoned mines has produced, in the shale and sandstone, a variety of burnt earths, which are of divers colours, some of them resembling riband-jasper.

The proofs of the strata having been altered by the heat of this dyke, are conclusive; for immediately beyond this band of china stone, the beds are indurated and somewhat altered to the thickness of about twelve feet, beyond which they pass into a micaceous, sandy, dark-coloured shale *a*, sometimes slightly calcareous, the unaltered Llandeilo flagstone of the district. Although the beds are hardened both above and below the trap, the overlying strata are the most altered. To the south-south-west, this dyke is lost in the mass of trap hills which terminate in the Corndon, but to the north-north-east it may be traced beyond Leigh Hall, where it finally subsides beneath the low country in the form of an amorphous, coarse concretionary, felspar rock. The concretions sometimes attain the size of a man's head, and being mixed with smaller lumps, the hillock in which they are exposed has quite the appearance, on a superficial glance, of being a pile of drifted matter or "diluvium." At this spot it forms the wall of a rich vein of lead ore, which strikes through the shale upon the side of the balls or concretions trap. From the few specimens I obtained, the ore of this vein appears to be of very rich quality, but its extent has not been ascertained[1]. Besides the ores of lead, I observed crystallized sulphate of barytes, iron pyrites, &c. This is the only well authenticated case of a good vein of lead ore having been found so far upon the western flank of the Corndon and Shelve Hills; for although similar trials have been made on the south-south-western prolongation of this ridge of Whitsborn Hill near Rorington and Little Weston, they have invariably terminated, after much expense, in discovering little more than appears on the surface in many of the natural ravines of the district; viz., large veins of crystalline carbonate of lime, sulphate and carbonate of barytes, &c. In the neighbourhood of Leigh Hall, are other lines and bosses of intrusive trap. A remarkable one is close to the high road, east of the house and within one

[1] The low level of this situation has occasioned the work to be stopped by water, but it has been recently resumed.

hundred yards of the bedded trap, described p. 271. Other masses of the same origin, consisting of fine crystalline greenstone, appear at the Grimmer Rocks; these throw off indurated schists on both flanks. Between the Corndon and the hamlet of Priest Weston, is the bold promontory of Llanfawr, throwing off the stratified deposits of Middleton. In this hill there are several varieties of felspar rock, some dark green and veined, which pass into a fine-grained, crystalline greenstone.

*Roundton* or *Roundtain, a hill,* so easily distinguished throughout Montgomeryshire by its round and knotty summit, consists for the most part of an amorphous mass of greenish-grey, compact felspar, of rough fracture, extremely hard and very slightly porphyritic. It contains carbonate of lime, both disseminated and in small veins, with minute crystals of iron pyrites: one variety is a dark-coloured very fine grained basaltic greenstone. This hill, like its neighbour the Corndon, is precipitous in its east-south-eastern face, and towards the west and south-west, exposes rounded protuberances of trap. One of these varieties at Brith Dir is an amygdaloid of granular felspar, containing kernels of calcareous spar, and resembling a trap rock which occurs at the Cefn, a small southern spur of the Breiddens; another is a mottled felspar rock, with crystals of common felspar and nests of iron pyrites.

*Todlethir* (pronounced *Taudley*) *Hill.*—In this hill, and at Symmond's Castle, its south-western termination, I observed

1. Dark greenstone, approaching to hornblende rock.
2. Porphyry, having a base of light-coloured compact felspar, with a few imbedded crystals of common felspar and hornblende.
3. Pale green porphyritic greenstone, having a tendency to columnar structure.
4. Greenstone, composed of equal parts of hornblende and compact white felspar, with a few crystals of pink common felspar.

These are occasionally traversed by veins of carbonate of lime.

These hills, being direct prolongations of the Corndon, form the central and chief ridge of eruption in this district; and their axis extends to the north-north-east through Stapely, by Bromlow Callow to the Grimmer Rocks, where coarse and fine grained greenstones jut out in rugged low protuberances, on the high road between Minsterly and Leigh Hall. The greenstone at Grimmer has a tendency to columnar structure, contains crystals of iron pyrites, and throws off highly inclined beds of shale to the north-west and south-east.

The hills of the Rovereas and Squilfa constitute the eastern parallels of the southern part of the district. The Squilfa is composed of coarse grained, light coloured greenstone, partly columnar, the columns rapidly exfoliating at their edges; it is, in fact, the Corndon in miniature. The Rovereas presents, in its western face, also coarse grained greenstone, which differs from that of the Squilfa in containing a greater proportion of dark hornblende and no white felspar. It is flanked on the east by fissile, compact felspar, apparently arranged in vertical beds, which graduate into decided volcanic grit or breccia, similar to that before mentioned; and still further to the east are the ordinary shale and sandstones of the district. If we try to follow the great basaltiform and irregular masses of greenstone, of the Rovereas and Squilfa in the direction of these ridges to the north-north-east, we soon find, as in the case of the Roundtain and Corndon, that the amorphous rocks suddenly subside, and are succeeded by bedded trap rocks, trending in the same direction. These are first seen in the hill of Cefn Gwynlle, and are prolonged to the north-north-east by the Rynis gate, Pell Radely, Ritton Castle, &c.[1]

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[1] In a traverse from the Squilfa, by Hyssington to Hurdley, and the flanks of Taudley, we meet with re-

Although the volcanic grits or bedded trap rocks occupy linear ridges in this tract, and amorphous masses throw off the former in various directions, it is not always practicable to separate with precision these two classes; in fact the one is occasionally seen to graduate into the other. Thus on the west and south-western face of the summit of the Corndon, the greenstone graduates upwards into a thinly laminated rock, dipping to the west at an angle of about 35°, which has been long worked for flagstones, the quarries having been opened to a depth of thirty to forty feet. The lowest strata have a decided trappean aspect, fold in large conchoidal flakes over the underlying greenstone, and from their composition must be considered as a sort of greenstone slate. These flaggy beds, splitting to a thickness of three to four inches, are of a dull grey colour, have somewhat a talcose and saponaceous feel, and a rough mechanical cross fracture. In the highest parts of the quarry, or further removed from the trap, it is difficult to distinguish them from sandstone flags. I could detect no organic remains in these beds, and I came to the conclusion that, though probably of an earlier date, they must, like others previously mentioned, have been formed during submarine volcanic eruptions. Stratified trap of precisely the same composition, occurs in a similar position on the south-western face of the greenstone of the Squilfa. (*Dysgwylfa.*)

These examples of transition from amorphous and massive, into slaty and bedded trap, seem to me to be highly valuable in illustrating one of the processes by which the rocks of this tract have been formed; for when the submarine volcanos were first in activity, they would naturally give rise to accumulations of finely levigated scoriæ, mud and sand, which would necessarily fold in layers round the edges of the bosses and cones of more solid igneous matter. Beds so formed would therefore be presented to us as one of the last links in the approach of volcanic grits towards true trap rocks; and such I conceive to have been the origin of the flagstones of the Corndon and Squilfa, which fold round the promontories, and pass into the intrusive greenstone.

Succeeding eruptions, of ephemeral character, but continued during long periods, would account for the numerous alternations of regularly bedded volcanic grit and marine sediment we have described; while, during a third æra of great disturbance, the amorphous trap being thrown up to great heights upon the same parallel lines of fissure, would break up and heave the stratified rocks into those anticlinal and synclinal lines by which this district is so beautifully diversified.

### *Principal Mining Ground.*

The most productive mining ground of this tract lies around the village of Shelve, which, although about 800 feet above the level of the sea, is still in a depression, being flanked on three sides by hills composed of the trap and altered rocks already described, and on the fourth by the lofty, serrated ridge of the Stiper Stones. The

petitions of the stratified courses of trap before described. The deposits in contact with the chief masses of intrusive trap in the southern part of the district are often much altered and veined, particularly in the hollows between the Roundtain and Taudley, where they contain nests and veins of sulphate of barytes, crystallized carbonate of lime, quartz and traces of lead ore.

necessary consequence of this configuration is, that the surface is wet, and the soil cold and sterile; for the waters descending from the surrounding ridges, lodge in this upland cavity, forming pools and morasses. The drainage of the district is effected by two small rivulets, which flow through the longitudinal furrows before mentioned. One, the chief source of the Onny, rising at Shelve and in the Hyssington marsh, runs to the south, and escapes by a narrow defile and fissure through the ridge of the Stiper Stones near Linley. (See vignette, head of chapter.) The other, rising near the Gravel mines, descends to the north-east by the gorge of Hope Mill, and falls near Minsterly into the Rea, a tributary of the Severn.

From the eastern foot of Stapeley and Corndon Hills, the ground rises towards Shelve in low undulations of sandstone and shale, which are traversed by several metalliferous veins wrought at the "Grit" and "Gravel mines." In the "White grit mines" are three veins which run diagonally across the strata somewhat in the form of the letter N. Of these, the central vein, called the Rider, strikes from west by south, to east by north; the flanking veins, called the "Squilfa" and the "Engine veins," range from south-east to north-west, and by their direction are supposed to unite with the Rider[1]. The "Rider" and the "Squilfa" are the most productive, and are now worked. The course of the "Rider" is marked on the surface by the protrusion of a mineral mass of highly inclined, quartzy hornstone, three or four feet thick. These veins traverse the sandstone and shale, the beds of which strike from N.N.E. to S.S.W. and dip 25° to the W.N.W. on one side of the hill, and to the east on the opposite side. The engine shaft is forty fathoms deep, other shafts are seventeen fathoms, but formerly the Squilfa vein was worked at seventy and eighty fathoms. The veins are very irregular in width, varying from six inches to six feet, and hade at a high angle to the S.S.W. There are two varieties of galena, the common and the steel grained; also carbonate of lead both crystallized and stalactitic. The other simple minerals are sulphate of barytes, crystallized quartz, and chalcedony, with a little lime and blende, the former sometimes coating crystals of quartz. The most beautiful mineral of these mines is the white stalactitic carbonate of lead[2]. The ore in the grit mine is also frequently associated with a decomposed, black, sooty substance, probably earthy oxide of manganese mixed with other materials, which sticks like paste to the ore and cannot be separated from it without much washing. A fourth and much smaller vein, called the "New Britain," runs nearly parallel to the strike of the strata, and is remarkable only in having afforded white carbonate of lead very near the surface. In all these veins many separate strings diverge from the chief body of "stuff," the best and richest ore being usually found in the bunches or points of intersection. The ordinary ores afford six to seven ounces of silver per ton. These mines, the property of Mr. More of Linley, are rapidly increasing in value, and when the contiguous marsh of Hyssington and Corndon shall have been drained (see note, p. 281.), it is probable that

[1] The Engine vein is not now in work, and the actual junction of the Squilfa with the Rider has not yet been proved, though the works at the present engine are very near that point where, if not suddenly terminated, they must from their direction unite. Captain Clements, the manager of these works, is of opinion that they do unite, particularly as the Squilfa vein is beginning to twist round suddenly towards the Rider.

[2] Dr. Du Gard informs me that some beautiful specimens of this stalactitic carbonate of lead, which I saw in his museum, occurred in cavities of the mining ground, which upon being penetrated by the pick-axe were found filled with water.

the veins will be found to extend further westward towards the eastern flank of the Stapely and Corndon hills. This surmise is at all events warranted in this district by the constant recurrence of vein stuff, where *large masses of stratified deposits* are contiguous to the *chief ridges of intrusive rocks*. The Gravel mines lie to the N.N.E. of the Grit, and after having been abandoned for some years are again coming into use. There are here three chief veins, two of which run more or less across the strata, as in the Grit mine; the third, proceeding from north to south, is only slightly oblique to the main direction of the chain. The last mentioned is called the Roman vein, and is said to have been worked to more than one hundred yards in depth by the Romans, whose mining utensils have been occasionally found in the galleries. A highly inclined band of compact felspar forms the wall or rider, and as this rises conspicuously above the surface it may have led to the first attempts of the ancient adventurers. The works are distinguished from those of modern date by the smallness of the drifts and the avoiding of those knots of hard rock which now give way before gunpowder. This vein hades sharply to the east, and dividing into two branches, passes through sandy schist, dipping N.N.W., which is so hard and micaceous as to resemble certain varieties of mica schist. It contains cubes of iron pyrites and small veins of quartz. The modern works have been sunk to the depth of 212 yards or 112 yards below the Roman galleries, and it is probable that they will now be followed to much greater depths, a steam-engine having been erected[1]. To the N.N.E. of the metalliferous ground of the "Grit" and "Gravel" are the "Bat holes" and "Wood mines." These have been abandoned for some time, but their geological relations are highly instructive. In one of the principal veins, the wall is granular felspar with green earth; and two contiguous bosses of crystalline greenstone, rising up unconformably through the strata of sandstone and shale, *cut off the productive veins*. In fact there has not been in this case a sufficient quantity of contiguous sandstone and shale to afford *ground* for the production of extensive veins, the bosses of greenstone which form part of the nucleus of the ridge of the Nick knolls and Santley Hill, rising up so very near the edge of the little valley. (Pl. 32. fig. 2.) This greenstone is highly crystalline, and breaks into rude columns. It throws off the strata to the east and west on each side of the intrusive ridge, and, as noticed on the side of the Wrekin and Caradoc, the sandstone on its western face is converted into quartz rock, and fractured masses of the same adhere to the steep acclivities and summit of the hill. China stone also occurs among these altered beds, some of which are horizontal, others broken, inclined, and vertical. In the deep cuttings to make the new road between this spot and Hope Mill, I found trilobites in the black schist and flag, identical with those of Llandeilo, with one new species of *Isotelus*, and many shells in the sandstone similar to those of the Caradoc formation. The veins were formerly worked at the Bat holes, but their productive qualities were found little persistent, and it is said that they were always cut out by hard masses of trap[2]. Phenomena like these have been also discovered in the shale on the sides of the intrusive masses of greenstone of the Round Hill, Buckstone, &c., by numerous trials, which, though successful in detecting small metalliferous veins and bunches of ore for short spaces, have been invariably stopped when the works reached the sides of the ridges of massive greenstone (sometimes basaltiform) which rise up

[1] It is probable that an antique pig of lead found in this district, and now in the possession of Mr. More of Linley Hall, was cast by the Romans from lead extracted at this mine. It bears the impress, IMP. ADRIANI. AUG. Its form is shorter and in every respect dissimilar to the shape of modern pigs of lead.

[2] I was informed by persons formerly interested in these works that the veins frequently reappeared on the opposite side of the intruding or sterile rock.

between the Nick Knolls and the Stiper Stones, no mineral veins in this tract having been found to penetrate trap rocks of intrusive character.

The previous observations apply to the western side of the mining tract. The eastern side, lying between Shelve and the ridge of the Stiper Stones, includes the productive mines of Snailbatch, Penally, and the Bog. The attention of geologists was first called to the rich Snailbatch mine by Mr. Arthur Aikin, a short extract from whose able description in the Geological Transactions will be found in the Appendix. I have only to add that it lies in veined schist and sandstone lithologically similar to those of the Shelve mines. On its eastern flank it is bounded by the Stiper Stones, and on the west by a line of highly crystalline greenstone which forms a dyke along the foot of Mytton's Dingle, the Black Hole, and the Crow's Nest to within a mile of Pontesbury. Although this great metalliferous bunch lies to the north-east of the district of Shelve, yet as it is situated between the ridge of the Stiper Stones and the axes of the eruptions of trap before mentioned, it must be considered as forming a part of the mining system of these hills.

The Penally mines, about three quarters of a mile to the west of the crest of the Stiper Stones, and about a mile and a half east of the village of Shelve, have been long abandoned, but are about to be again wrought. One of the veins, running nearly east and west, is remarkable in affording a spring of water of higher temperature than the other neighbouring springs, and has thus acquired the name of "warm water vein." Hence to the "Bog" mine the ground is more or less starred with veins, though without the appearance of any trap rock near the surface.

In the Bog mine are three master veins, trending (like those of the Gravel, Grit, and Snailbatch,) more or less at right angles to the direction of the trap ridges and the associated strata; but there are many branches which cross each other. These veins hade together. One vein was followed till it reached the wall of quartz rock of the Stiper Stones, by which it was deflected, and being followed for a certain distance along the side of the quartz rock was lost. The metalliferous portions of these veins vary from six inches to two feet. The shaft was 200 yards deep when I last visited these mines (1835), but the works have been since extended, and the veins are now pursued to greater depths[1]. The mining measures, as in many of the other cases, consist of black shale with quartz veins, and they dip westward or from the Stiper Stones. Many beautiful specimens have been obtained in the Bog and Penally veins of the same simple minerals found in the Grit and Snailbatch. Between these and the Grit mines the metalliferous veins are, in the language of miners, "*cut off by the shale.*" This fact is of importance in explaining the intimate connexion between such veins and the intrusive rocks, for this intervening space, though surrounded by centres of eruptive action, is so far removed from them, that the strata of shale and sandstone are little altered, and therefore not penetrated by veins. In these beds I have found many remains which unequivocally identify them with the lower rocks of the Silurian System. (See organic remains and localities.)

The tract between Hyssington and Shelve is occupied by a number of alternate ridges of trap and depressions in shale and sandstone. All these linear and interstratified traps in this part of the district are regularly bedded, with the exception, perhaps, of that of Cefn Bank, which is ill exhibited, and from its rounded form presents no distinct features. The other ridges, when closely examined, present escarpments, the beds dipping away either to the W.N.W. or E.N.E.,

[1] My friend, Mr. Joseph Walker, one of the present proprietors of these mines, has furnished me with a statement of their produce in different years. See Appendix, where the average produce of the whole tract is also given.

the strike of all being persistently to the N.N.E. The most marked of these hills are Cefn-y-Gwynlle, the Bank, Mugglewick, Radely, and Ritton Castle. Cefn-y-Gwynlle, which rises to a height of 1100 feet, is composed of greenstone and grey felspar rock (a sort of pseudo porphyry), the latter passing into what has been called volcanic breccia, large masses of which are interlaced with some schistose beds, and throw off others upon their flanks. This hill is full of small and poor mineral veins which traverse the strata, and numerous trials have been made in various parts. One of these trials was in progress from the western flank of the hill when I first visited the district (1832). A gallery had been driven across the inclined strata and passed through the following rocks:

| | Yards. |
|---|---|
| 1. Trap, consisting of greenstone made up of common felspar and hornblende with much carbonate of lime; slaty in parts | 40 |
| 2. Brecciated rocks | 20 |
| 3. Thinly foliated black shale with white quartz veins | 10 |
| 4. Compact flaggy felspathic rock (Query, indurated shale or compact felspar rock?) | 40 |
| 5. Trap; greenstone with crystals of hornblende and felspar; lime disseminated | 12 |
| 6. Indurated schist, with many veins of quartz, containing crystals of iron pyrites. (Here a vein of lead ore was met with.) | 120 |
| 7. Vein stuff, containing sulph. of barytes, calcareous spar, and a little lead ore. This vein was very thin, and being followed out to the north-east disappeared in a mixed shaly rock. The work proceeded again in the same matrix as No. 6. but the trial entirely failed[1]. | |

Near the Rynis Gate, a cut recently opened by the new road has exposed a succession of trappean masses alternating with indurated schist in the following ascending order, and dipping E.S.E. at an angle of 40° to 45°.

*a.* Thick beds of felspathic breccia, containing fragments of indurated schist with crystals of iron pyrites; some of these pass into layers of grey and whitish colours so purely felspathic that no foreign ingredient can be detected: all the beds cleave in the direction of the planes of lamination.

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[1] The most decisive proofs of the subterranean existence of alternations of trap and shale have been met with in driving a tunnel to drain this wet and upland mining tract. The tunnel opens into the low country near Leigh Hall, and as its course thence is to the south it necessarily traverses in a slightly oblique direction all the alternating masses of rock which are interposed between its mouth and the mining ground. These alternating masses are in fact the very rocks we have been just describing, and rise to the surface in the Callows, Notmoor, and Lordstone Hills. In 1835 the work had proceeded upwards of a mile from its mouth, and had passed through the following rocks:

| | Yards. | | Yards |
|---|---|---|---|
| 1. Shale, &c. | 120 | 8. Shale | 76 |
| 2. White rock (the China stone described) | $4\frac{1}{2}$ | 9. Trap | 61 |
| 3. Trap | 56 | 10. Shale | 13 |
| 4. White rock, as above (altered sandstone, &c.) | 6 | 11. Trap | 118 |
| 5. Trap | 114 | 12. Shale, &c. | 987 |
| 6. Shale and Sandstone | $124\frac{1}{2}$ | | |
| 7. Trap | $297\frac{1}{2}$ | Yards | $1977\frac{1}{2}$ |

As this level had been for some years in progress, I had not an opportunity of examining the precise nature of all the different rocks which were traversed. From the external features of the intervening tract which remained to be perforated, it is probable that most of the hard rocks have been already cut through, and that the work would reach the mining ground with few additional obstacles. This adit is seven feet high, and six feet wide.

*b*. The felspar rock is overlaid and underlaid by parallel layers of indurated schist splitting into irregular prisms and rhombs.

*c*. Greenstone highly crystalline, very ferruginous on the exterior: it forms the cap of the indurated schist. In a few yards the bedded rock (*a*) is repeated, having quite a subcrystalline character with crystals of felspar, yet entangling very large fragments of indurated schist. This point is the south-south-western extremity of Mugglewick Hill.

If we examine the ridges between Mugglewick and the Stiper Stones, we perceive that in the short space of half a mile the inclination of the strata is completely reversed, and that they all dip away from the Stiper Stones at 45° and 40°. In Pell Radeley no distinct signs of stratification can be detected; masses of hard porphyritic and other felspar rocks appearing through the turf in irregularly columnar shapes. These rocks are within 200 or 300 paces of one of the boldest and most broken points of the quartz rock of the Stiper Stones. In the Brook Hill, however, and in the parallel ridge of Ritton Castle (Pl. 32. f. 2.), trap and shale are as clearly interstratified as any we have mentioned, and both dip at rapid angles to the north-west. The Brook Hill may be considered the prolongation of Cefn-Gwynlle, and in it we see various bedded felspar rocks plunging under those of Ritton Castle. In the latter are thick beds of concretionary felspar rock, passing upwards into felspar breccia like that so often mentioned, and these, after alternating several times with sandstone and shale, are overlaid by highly ferruginous, thinly laminated schists. A vein of lead ore crosses the alternating beds of felspar, breccia, and shale, but does not appear to continue towards the mass of true trappean rock; a gallery was formerly driven in, but is now abandoned. This vein is two to three feet wide, and is directly at right angles to the strike of the strata, which are at this point a little deflected from their regular bearing of N.N.E. to E.N.E. They dip 45° N.N.W. To the north-east these stratified traps of Ritton Castle are lost in the low, wavy ridges which only slightly diversify the arid moorlands, between the mining district of the Bog and Penally on the east, and that of the grit and gravel mines on the west.

I have thus attempted to give a sketch of the manner in which this district is traversed by a variety of veins which are more or less productive of lead ore. In a plan of Mr. More's of Linley Hall, the chief proprietor in this district, upwards of twenty-four are laid down in the district of Shelve alone, excluding the tracts around the Bog and Penally; so that, comprehending the principal portion of the mining ground, we may say that it contains upwards of thirty metalliferous veins which *have been* profitably worked. Adding to these the numberless poor and small lead veins in the extremities of the district, and all those which although containing only sulphate of barytes, quartz, and lime, have been produced by the same causes as those which bear lead, we shall find there are few tracts of given extent in any part of the world which are veined to a greater extent. Whilst all the masses of trap rock, whether intrusive or interstratified, range parallel to the strike of the associated strata, viz. from N.N.E. to S.S.W., the metalliferous veins are in most cases transverse or oblique to such direction. In some instances, indeed, they are only very slightly oblique to the strike, as in the Roman vein, but in the great majority of instances they are more obtusely transverse to the prevailing direction of the strata, or radiate as it were across those beds of surrounding shale and sandstone which are contiguous to bosses of intrusive greenstone. In no instance, however, do they continue *through* the latter. At the same time they occa-

T. Webster del.

A. Picken Zinc.

" The Vale of Shrewsbury .

THE STIPER STONES .

sionally pass through some of the stratified volcanic grits which have been shown to be contemporaneous with the strata of the Lower Silurian rocks. With these facts before us, there is surely nothing unreasonable in the theory which assumes, that whether these veins have been formed by electricity, galvanism, or other chemical agency, they were intimately connected with volcanic or igneous agency. That the intrusion of volcanic rocks has been one of the principal causes in the production of these veins is, indeed, strikingly apparent from the fact, that in proportion as you recede from these outbursts, the veins become scarcer and finally disappear; whilst the great mass of them occurs precisely in that portion of the sandstone and shale which is most furrowed by linear eruptions. Again, when we quit the western flanks of this volcanized tract, we leave behind us all the veins, the great undulating Silurian masses of the Long Mountain being entirely exempt from such; but no sooner do we approach the Breidden Hills, another volcanic chain, than veined stones are once more abundant in the altered and contiguous strata. (Pl. 32. f. 1.)

### *The Stiper Stones.* (Pl. 32. f. 1, 2, and 3.)

(See the opposite view[1], and the vignette at the commencement of the chapter.)

There is not, perhaps, a more singular feature in the physical geography of England than the Stiper Stones. These rocks are made up of a number of broken and serrated ledges, jutting out to form the summits of the hills which flank the volcanized mining district of Shelve, at heights varying from 1500 to 1600 feet above the sea. They stand out on the crest of the ridge at short intervals, like rugged cyclopean ruins, some of the principal of which are about 50 or 60 feet high, and about 120 or 130 feet in width. The slopes of the elevated moorlands from which they protrude are covered with coarse detritus of the same rock. The main range of the serrated points is from N.N.E. to S.S.W., and therefore conformable to the strike of the adjoining district of Shelve; but when examined in detail, this ridge is found to be intersected by a number of transverse faults, dividing it into separate masses, some trending 25° and 30°, others only 10° and 15°, to the east of north and west of south. Passages across the ridge are of course most easily made in the hollows between these disjointed "serræ" of quartz rock, as, for example, by the mountain track to the east of the Bog mine. The only fracture, however, which has produced a deep gorge is that by which the river Onny escapes from the upland district of mines. The Rev. John Parker has enabled me to present to the reader, the contrast between this rugged mass of quartz rock on the north side of the gorge, and the rich woody demesne

[1] The accompanying view, for which I am indebted to Mr. A. Aikin, was drawn by Mr. Webster. It gives a perfect notion of some of the most northerly of these masses overlooking the vale of Shrewsbury.

of Linley watered by the stream issuing from the defile. (See the vignette at the head of this chapter.)

Although the Heathmont, west of Linley, constitutes geologically the south-western termination of this ridge of quartz rock, and Pontesbury their north-eastern extremity, thus giving the range a length of ten miles, the central or lofty portion for about four miles is alone known in the country under the name of the "Stiper Stones."

When I first examined these rocks, I felt a difficulty in comprehending their true nature, not being at that time acquainted with those of similar structure, which on the flank of the Caradoc and the Wrekin have been proved to be simply altered deposits. A second visit to this ridge dispelled the obscurity. Instead of a chaos of broken masses, split by numerous joints which had become open fissures, and piled up in heaps very like the grouping of certain basalts, I was then able to trace lines of stratification, which although obscure in the centre of the masses, marked a dip to the N.N.W., varying from 40° to 70°. Though many large loose blocks have rolled down on both sides of the ridge, they are in much the greatest abundance on the eastern face, where they have fallen from the escarpment and are strewed down the steep slope in deltoid "écroulemens."

The rock of the Stiper Stones is quite analogous to that of the Wrekin and of the Caradoc, exhibiting passages from compact and granular quartz rock into quartzose grit and sandstone having a regular bedding. In its most crystalline form it is intersected by numerous veins of vitreous quartz, and when weathered, numerous small, white facets of quartz crystals are exposed, in vivid contrast to the dull brown colour of the heath on which they lie. That these are merely fused sandstones, in which the traces of mechanical deposit have been rendered obscure, is seen both by following the ridge upon its strike to the N.N.E. or by tracing the passage of the quartz grits into the overlying strata. In the first case, in tracking these rocks to the north-east, we no sooner quit the flanks of this convulsed district of mines, than we find a zone of quartzose grit and sandstone passing into a conglomerate which extends along the hills of Bleak Moor, &c., the ends of the strata being best exposed in Nils Hill near Pontesbury.

At Nils Hill the quartz ridge may be completely investigated in two transverse combs, in the northern of which the rock is largely quarried for the roads of the adjacent district. It is at least 200 paces wide, and the strata in the principal quarries dip 60° and 70° to the W.N.W. and strike 15° to 20° to the east of north and west of south. The upper beds are thin, and succeed each other rapidly, without interposed laminæ of a different substance; but the underlying strata towards the centre are two to four feet thick, with occasional traces of way boards of sandy shale, the lowest beds being pebbly quartzose grits, separated by laminæ of steatitic greenish shale. Throughout large portions, however, the character of granular quartz rock is nearly as well maintained as in the peaks of the Stiper Stones. On the surface of some of these beds are broad, wavy undulations and even ripple-marks so common to arenaceous deposits. Together with these, are also ramose casts, which, though strongly indicative of organic origin, could not safely be referred to any known

genus[1]. Another form, still more resembling an organized body, which I detected in my last visit, is probably an orthoceratite.

Small flakes of anthracite occur, though rarely, in cavities and joints. The same rocks continue from Nils Hill to the village of Pontesbury, near which their north-western face is covered by a "breccia in place" of angular lumps of the quartz rock, forming thick beds, which hanging upon the side of the hill constitute the fringe of the adjacent coal-field, towards which they dip at a slight angle, thus presenting a strong contrast to the highly inclined parent rocks on which they rest[2].

The quartz rock of Nils Hill is so well exposed in quarries, that we acquire a much more precise knowledge of its structure than in the weathered and dismantled bosses of the Stiper Stones. We here see that on the opposite sides of the transverse combs the directions of the strata of quartz rock diverge in their direction and have different degrees of inclination. On the north-north-eastern side of the comb in which the great quarry is situated, the chief mass trends from 15° and 20° west of south to 15° and 20° east of north, and dips 60° to 70°; whilst on the south-south-western side the same beds striking north and south are vertical, and even in part thrown over beyond verticality. The nature of those transverse fractures which have broken up the ridge of the Stiper Stones into a number of disjointed and separate ledges is thus explained; for we perceive that it would have been impracticable to tilt these once continuous strata into the divergent directions in which they are now placed without producing transverse ruptures or faults. So vibratory and oscillating, indeed, have been the movements by which the strike of the masses has been determined, that even in the same ledge we meet with differences of direction, amounting to 30° and 35°, in beds only fifty to eighty feet from each other in the order of superposition.

Nils Hill is further an excellent spot to observe the numerous joints into which the quartz rock is divided, and which have been alluded to as obscuring the true lines of deposit in the Stiper Stones. The prevalent joints form backs, i. e. their planes are at obtuse or right angles to the surfaces of the beds. Most of the joints trend diagonally to the strike, so that the true dip of the strata lies in a direction between these diagonals, as in many cases previously alluded to. (See jointed structure of Upper Silurian Rocks, chapter 20.) There are, however, examples of other joints which mark the true lines of strike and dip. Referring to the Appendix for other observations on joints, it is sufficient to state that at this spot they have given relations to the strata, and that their direction changes with every variation in the strike of the mass.

The rock of the Stiper Stones passes upwards into sandstone, which in its turn dips under the schists forming the mining ground of Snailbatch and Penally, &c. These transitions in the ascending order are exposed on the sides of the deep and picturesque ravines of Mytton's Dingle[3], the Crow's Nest, &c.

The conversion of sandstone into quartz rock having been shown to take place in several points where such strata are in contact with rocks of igneous origin both in this district and other parts of Salop, there can be no doubt that the structure of the Stiper

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[1] In perusing a MS. of Mr. Arthur Aikin, I perceive that he also observed what he considered to be fossils in this quartz rock near Pontesbury.

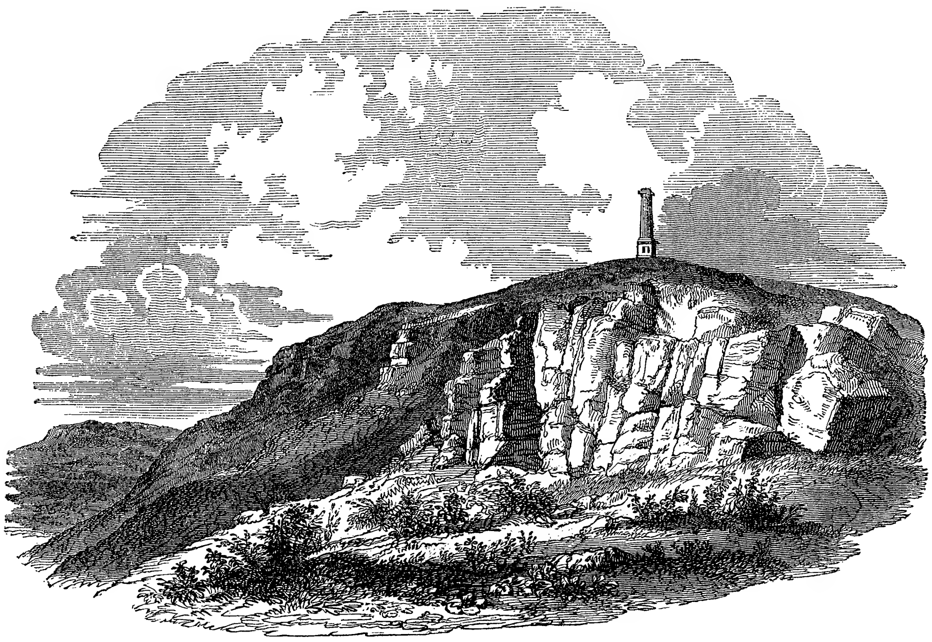
[2] A similar breccia recomposed *in situ* occurs on the summit and sides of the Lickey quartz rock.

[3] Vulgarly called Mutton Dingle.

Stones has resulted from similar action. For, although in this case the absolute contact of the sandstone with such rocks is not exposed, as at the Wrekin and the Caradoc, linear eruptions of trap are seen on both sides of this massive wall, associated with metalliferous veins and highly altered and contorted rocks. In short, these quartz rocks are encased between two parallels of igneous action; comprising Pontesford Hill, Habberly, the Cauf Knolls, and Linley, on the east; Corndon and the Shelve district on the west. That the Stiper Stones are simply sandstones changed into quartz rock is further proved by the recent workings of the Bog mines (the nearest to the mountain side), the horizontal drifts from which, as already stated, when carried in towards the hill, proved that the quartzose mass rises up from beneath in a mural form, cutting off the mineral veins and deflecting them through the overlying schists and sandstones, both to the north and to the south.

The Stiper Stones are remarkable in another sense, as being the barrier which separates two metalliferous tracts of very different characters. On the west all the veins are of lead ore; on the east they contain copper and no lead ore. (See the last chapter and Pl. 32. figs. 1 and 2.) Comparing small effects with great, this diversity of metalliferous veins on the opposite sides of a ridge of metamorphic rock, is in accordance with a phenomenon observed by Humboldt on the opposite flanks of the great chain of the Ural[1].

[1] Fragmens Asiatiques.



45.

*Summit of the Breidden, from a drawing by Mr. T. Webster, F.G.S.*

## CHAPTER XXIII.

### *The Breidden Hills, with other Trap and altered Rocks in Montgomeryshire.*

*Line of Dislocation produced by the Eruption of the Breidden Hills shown to extend through Shropshire into Staffordshire.* (Pl. 32. figs. 5, 6, 7 & 8.)

THE chief phenomena explained in this chapter are connected with the Breidden Hills, so justly admired for their picturesque forms when viewed from the surrounding region. As, however, the exposition of their relations will naturally lead to some important inferences with which this chapter must terminate, I first describe certain minor detached trap rocks of the same neighbourhood.

In the Vale of Montgomery, about two miles west of Chirbury and three miles from the western flank of the Corndon Hills, described in the last chapter, trap rocks again rise up in three places, on a line running from north-north-east to south-south-west. The most northern, called Nant-Cribba, is a small boss, situated a little to the south of the point where the road from Bishop's Castle and Chirbury unites with that from Montgomery to Welch Pool. Having been long used for the roads, excavations have been formed in the rock about one hundred yards in breadth, and

thirty to forty feet in depth. The prevailing rock is greenish and purple felspar, partly concretionary, passing into hard felspar porphyry, and rising through vertical, dislocated and contorted beds of indurated sandstone. On one side I observed these beds dipping 80° north-north-east, as expressed in this wood-cut.

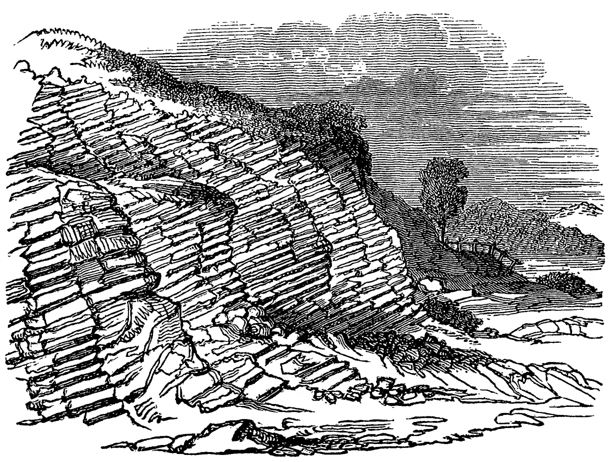
N.N.E. S.S.W. 46.


*a.* Unaltered shale. *b.* Shale contorted, &c. *c.* Altered rock. *d.* Trap.

Similar trap reappears at Stallow, two miles south-south-west of Nantcribba, where it is also partially quarried, and half a mile further upon the same line is another outburst, forming the bold precipitous rock on which stands the ancient Castle of Montgomery. On its northern face, which is vertical and about eighty feet in height, this rock has been much quarried, not only as a road-stone, but for coarse building purposes. The general colour of the rock is light-green, and the predominating structure is concretionary, being composed, for the most part, of a fine granular felspar, slightly porphyritic, with veins of white carbonate of lime, and occasionally minute nests and flakes of anthracite; it is split by many transverse fissures, and has some appearance of being traversed by dykes. The sandstone and shale, in contact with the trap, are tilted and dislocated, as seen on the bluff north-east and north-western faces. At the south end, but detached from the trap, are highly inclined beds of sandstone flag containing *Graptolites*. In the loftier and adjacent hill of Fridd Baldwin, separated from the castle rock by a deep dingle, similar beds of flagstone are nearly vertical and much contorted. These flagstones, dipping away to the west and north-west, mark one of the flanks of the axis of elevation, due to the eruption of the trap of Montgomery Castle, Stallow, and Nantcribba. Between the Nantcribba trap and Welch Pool, are undulating hills of shale, but near the town on the left bank of the Severn is another outburst of trap.

### *Trap of Welch Pool.*

47.

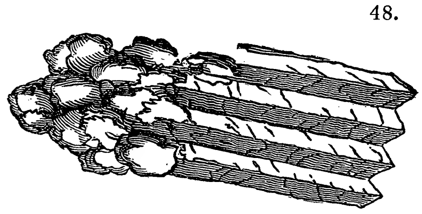


*View of the Standard Quarries, from a drawing by Lady Lucy Clive.*

The trap rock of the Standard quarries in the suburbs of this town, is a portion of a large dyke, which cuts through beds of the Caradoc sandstone and associated limestone and shale in a direction from N.N.E. to S.S.W. It has been exposed to a width of about 120 paces, and a maximum height of upwards of 100 feet. A great portion of the mass is arranged in columns (as expressed in the above vignette), inclined 20° to the S.W.: the ends of the prisms, as seen at the north-eastern face of the dyke, (being at right angles to the highly inclined strata through which the dyke passes,) dip 70° to E.S.E. The columns are divided by joints at right angles to the axis of the columns, or parallel to the strata, on the sides of the dyke, and the workmen are thus enabled to extract large blocks with great facility. This rock, though of unquestionable volcanic origin, is remarkable from being most easily worked and well adapted for architectural purposes. The best stone is of a light green colour, and is extracted from the centre of the dyke, where the prismatic structure is most distinct, the distance between the transverse joints being frequently seven to ten feet.

This light green variety is essentially made up of granular felspar, speckled with many minute nests and sometimes kernels of calcareous spar. It contains also crystals of common and arsenical pyrites; the joints of these prisms are partially coated with serpentine, and where the rock is concretionary, the same mineral occasionally envelopes the concretions. Sometimes the joints are lined with thin films of green earth and anthracite, in minute quantities. The soft and sectile nature of this columnar trap, is probably due in some degree to the state of aggregation of the grains of felspar, but doubtless in a greater, to the equable diffusion *of small particles of lime.* Another variety, better seen in the flanks of the quarry, is blue, harder, more compact, very slightly calcareous, and fit only for the roads; it passes into common greenstone without lime. A third variety is a grey granular felspar: a fourth, in the north-eastern prolongation of the dyke, at the spot called the "Old Dog Kennels," is entirely composed of very large concretions, some of which consist of granular felspar, hornblende, and lime. When their surfaces are slightly decomposed, the oxydized iron of the hornblende defines the outline, as if the concretions were encircled by a number of rusty hoops.

48.



The sudden passage from the fine-grained columnar, into the coarse and large concretionary trap is beautifully displayed at the south-west end of the quarry, beneath a small garden. The columnar rock has here a hard, brittle and conchoidal fracture, and the ends of the prisms pass at once, as expressed in this wood-cut, into the concretions, which vary in size from large gourds to a man's fist: the same rock also occurs in the Moel-y-Golfa Hill, p. 292.

The south-eastern and south-western walls of the Welch Pool dyke, consist of highly altered rocks. Shale and sandy limestone are seen near the Old Dog Kennels; at one point of contact with the trap, the granular structure of the calcareous sandstone is gone, and replaced by a thin zone of grey, hard, and slightly calcareous quartzose matter; at another, a few feet of dull grey encrinital limestone, is penetrated by large veins of white calcareous spar. The beds dip 80° south-east; a thin band of bluish clay, apparently little altered, is, however, partially interposed between

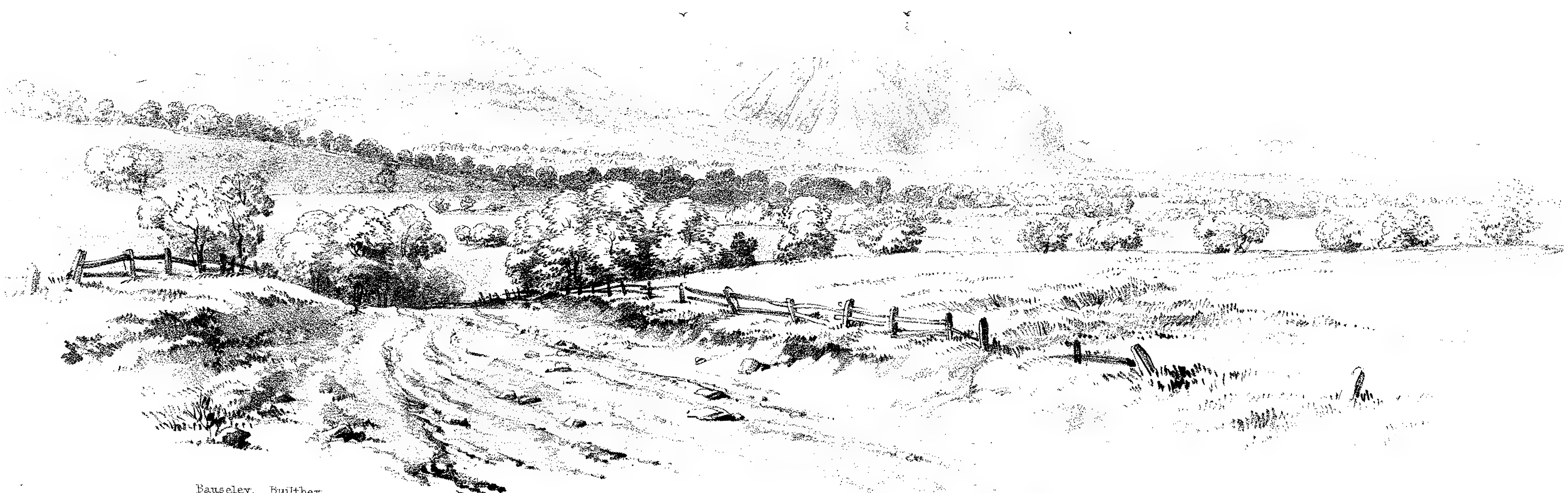
these calcareous beds and the grey granular felspar rock. These impure limestones belong to the Caradoc formation, and will be further described in the ensuing chapter.

A very hard, heavy, and much altered rock, has been recently laid open on the western side in improving the road to Guilsfield, some portions of which are with difficulty distinguished from the trap itself. The general aspect, however, and above all its possessing the character of a stratified deposit, the joints diverging from the line of the dyke, enable us to decide that the mass is a part of the Silurian system, though highly altered by the trap which traverses it. The principal joints here range from north-west to south-east, are vertical, and completely distinct from any lines of structure in the body of the trap rock.

This dyke disappears to the north-north-east under hills of reddish Caradoc sandstone, the strata of which are much dislocated; and to the south-south-east similar effects are traceable in Powis Castle Park, at several parts near the Castle; the highest or calcareous beds of the Lower Silurian rocks being elevated into highly inclined positions, throwing off the Upper Silurian or mudstone rocks. Strictly speaking, the axis determined by the dyke of the Standard Quarries, whether measured on its immediate flanks, or by reference to these lines of disturbance, is from N.N.E. to S.S.W., but if viewed upon a larger scale, it will appear that the dislocation in the higher ridge of the Upper Park changes its direction to E.N.E. and W.S.W., according with that of the Breidden Hills, and it is therefore possible, that the dyke of Welch Pool, and the lines of disturbance immediately proceeding from it, are only slight aberrations from a line of eruption of which the Breiddens was the chief focus: it is, however, to be observed that the disturbed line of Welch Pool is parallel to the strike of the volcanic ridges of Corndon, whilst the Breidden Hills, next to be described, cut through the stratified deposits in a direction which diverges 45° from those parallels.

### *The Breidden Hills.*

These hills present two principal masses, the Breidden and the Moel-y-Golfa, which extend from W.S.W. to E.N.E. in parallel ridges. Their summits consist exclusively of trap, and they are separated by depressions in sandstone and shale. The Breidden, which gives its name to the group, impends over the Severn in bluff faces, and its rounded summit, 1199 feet above the sea, is surmounted by the pillar which commemorates the victories of Rodney, as expressed in the vignette at the head of this chapter. The Moel-y-Golfa having a conical form, attains the height of 1143 feet, and forms the south-western end of the largest ridge, which extends four miles into Shropshire in the hills of Middleton, Cefn-y-Castel, Builthey and Bauseley. The Criggan is a low central elevation, which, when viewed from Welch Pool or the south-west, has the appearance of a third parallel ridge, but it soon subsides. The Breidden is terminated on the north-east by an expansion or contrefort called Brinford Wood. These picturesque hills present themselves in very devious forms when viewed from different points of the surrounding




T. Webster del.t

BREIDDIN HILLS, FROM NEAR NESSCLIFF.

Day & Haghe Lith.rs

country. Thus their outline, as seen from the north and north-east, is expressed in the opposite sketch, in which the Moel-y-Golfa and its dependencies constitute a separate undulating ridge, diminishing in height as it advances to the north-east; while the Rodney Pillar, or the true Breidden, appears as one heavy mass. Again, if viewed from the south-west, Moel-y-Golfa appears like Vesuvius, while the Criggan and Breidden form two other distinct conical ridges. (See Drawing prefixed to ensuing chapter.)

The general relations of these hills are similar to those of some of the ridges already described. They exhibit (though rarely) indications of contemporaneous trap, alternating conformably with beds of sedimentary origin, as in the Shelve country. The chief rock, however, is of intrusive origin and has been forced through previously formed Silurian strata, masses of which are either inclosed between the ridges of trap, or thrown off by it in vertical and dislocated patches.

The prevailing mass in the Breidden properly so called (Rodney Pillar Hill), is a coarse-grained greenstone, arranged (near the summit) in rude columnar masses, as expressed in the vignette, p. 287. On the south-western and most precipitous face of this hill overhanging the Severn, the greenstone is porphyritic, and passes into small concretionary and fine granular felspar rocks, with disseminated carbonate of lime. In some places it assumes the characters of clinkstone, and in others it is an amygdaloid, containing kernels of calcareous spar. The colours vary from dark green to light grey and blue: one of the small concretionary varieties (green with white spots), protrudes in a small boss beyond the north-east termination of the Breidden, at a spot called Belem bank close to the Severn, and from its hardness has been long quarried for the Shrewsbury roads. This mass of trap, about 100 feet in height, forms, like that of Welchpool, a great dyke exposed to a width of about eighty paces. In parts the trap divides into coarse columns, inclined at an angle of 40°, and the faces of the fissures or joints are covered with matter coloured green by chlorite. The rock itself is fine granular felspar, tending to a small concretionary structure. It is partly amygdaloidal and cellular, and is occasionally traversed by veins. The Voel, a round, detached hillock, at the south-western or opposite extremity, is a coarse-grained greenstone. The Breidden itself, having upon three sides precipitous faces which rise abruptly from the flat vale of the Severn, offers few clear evidences of association with the stratified deposits, except upon its east and south-south-eastern or hilly side, where dislocated and broken patches of shale adhere to the trap. The Criggan exhibits several knots of trap in forms more or less columnar; at the New piece, the trap pierces the sandy shale, the beds of which are vertical, fractured, and in parts converted into a silicified slate. The most instructive instance of the ancient or bedded trap analogous to those cases described in the Shelve and Corndon districts, is at Bauseley Hill near the east-north-eastern termination of the ridge. The centre of the trap is laid open by extensive quarries, and it consists chiefly of a large concretionary felspar rock, in parts porphyritic, which is flanked on the north-west by a vertical wall of sandy greenish schist, slightly micaceous, with little or no appearance of having been altered. This is followed by a thin course of greyish-blue, granular felspar rock, succeeded by finely laminated, soft shivery, black shale, perfectly unaltered. The shale is again followed by bands of felspathic trap, partly porphyritic and passing into greenstone. They are about four yards thick, and flanked by a trappean aggregate, containing fragments of schist, and casts of fossils precisely like those described in the Shelve country. It is from twenty-five to thirty feet thick, regularly bedded, and towards the exterior passes into a greenish-grey sandstone, evidently formed of volcanic submarine dejections.

Similar sandstones are found on the other side of this hill, dipping to the south-south-east at angles of eighty and seventy, and passing under the ordinary shale of the district. This transverse section of Bauseley Hill is so clear, that no one can examine it without being convinced that the felspar rocks were formed contemporaneously with the shale and sandstone with which they alternate; for the planes of deposit of the beds of micaceous sandstone and black shale, are exposed like the sides of party-coloured walls, interstratified with the beds of trap and felspar aggregates. The evidence is further most valuable in showing, that as the Silurian deposits and the alternating traps are not in positions in which they could have been deposited, they must have been thrown into their present vertical positions by convulsions. Continuing this transverse section to the north-west, across a little dell, we come to a conical knoll of intrusive trap rock, which piercing through the strata, dislocates and throws them off abruptly. This rock is made of compact felspar, sometimes porphyritic, containing crystals of common felspar, associated with concretions of green earth and a little disseminated lime. The diagram, Pl. 32. f. 7., will explain the relations of the stratified and intrusive trap rocks to the sedimentary deposits.

The summit of the Moel-y-Golfa is a slaty porphyry with a base of compact felspar, and has a tendency to columnar structure. It passes on one side into a coarse-grained greenstone, and on the other into a large concretionary trap. The last variety is deeply cut into at the foot of the hill nearest to Middleton, where the large size of the concretions well entitle the quarries to a visit. They consist for the greater part of compact felspar, sometimes porphyritic, and their colours usually differ from those of the matrix. This rock, indeed, is exactly the same as that described on the sides of the Welch Pool Dyke. It reappears at various points along this ridge, particularly in the little bosses between Builthy and Bauseley. Wherever this rock has been long exposed above the turf it has the aspect of a bronze-coloured quartzose conglomerate[1].

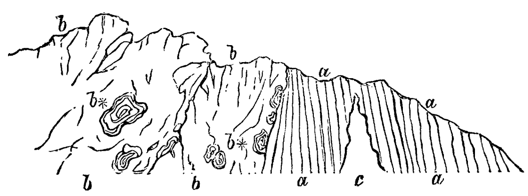
The hill of Cefn-y-Castel offers little clear evidence of structure. At the south-west end of Moel-y-Golfa the trap of the detached hillock of Little Garreg is rather remarkable, consisting of spotted, fine concretionary greenstone, with small nests of white and black calcareous spar. This spotted rock, passing also into amygdaloid, reappears at a place called the Cefn, on the east side of the road from Shrewsbury to Welchpool, and about four miles from the latter. Iron pyrites is disseminated in minute crystals, and white calcareous spar, coats the rifts of the rock and also penetrates it in veins. Some varieties contain white calc spar enveloping small kernels of green earth, and the dark spots and the discoloration of the flakes and nests of carbonate of lime are probably due to this mineral. This rock is quarried for the roads, and the excavations offer satisfactory evidence of the violent intrusion of the trap into the associated strata. It has risen in round masses, throwing off the schist and sandy limestone, and where the masses have been quarried out, large cavities have been left, the roofs of which exhibit the stratified deposits highly curved and broken. The junction bands are chiefly black, laminated, flinty schists, with some minute stripes or veins of lead ore and steatitic matter: in parts the trap rock is intruded, with jagged edges, into contiguous beds of sandy impure limestone, which on contact are more or less crystalline and indurated. Another variety of these contact rocks is a breccia of dark-coloured, indurated sandstone, almost quartz rock, with veins of calcareous spar and iron pyrites. At the south end of this low rising ground, consisting of upper Silurian rocks, as proved by the fossils, and where there is no trap, the stratified deposits are unaltered and preserve a strike from north-east to south-west; but on the north side of the boss of trap they belong to the upper calcareous beds of the Caradoc sand-

[1] See account of a similar large concretionary trap at Leigh Hall, p. 276.

stone, and the strike is north and south. These are the oldest strata brought to day in this neighbourhood. The other fossil evidences collected from the shale on the flanks of the Moel-y-Golfa ridge, are *Euomphalus* and *Cardiola*, of the Upper Silurian rocks.

The most marked changes in the ordinary lithological characters of these deposits are seen all along the Moel-y-Golfa and Middleton ridge, of which the Cefn is a prolonged spur. Some of the most striking have been exposed by the works on the sides of the hill of Middleton, situated between the Moel-y-Golfa on the south-west, and Cefn-y-Castel on the north-east. This hill is traversed by several dykes of compact, light green, white and buff felspar, with minute veins of rose-coloured quartz. The sides of the upper part of the hill present the appearance of irregularly stratified masses, arranged in an inverted cup-form, the strata dipping inwards, and consisting of felspathic sandstone and schists, alternating with felspar breccia entangling fragments of schist, similar to the rocks described at Brownlow Callow near Shelve, with flakes of steatite. One of these conglomerates contains rounded portions of steatite and fragments of granular felspar, another has carbonate of lime diffused through grey granular felspar. These are overlaid and underlaid by bulging masses of a coarse concretionary felspar rock[1]. The varieties of the felspar most uniform in structure have been worked for various economical purposes, as the manufacture of china, &c. There are also large veins of sulphate of barytes, with crystallized carbonate of lime, sulphuret of iron, &c. The compact felspar passes into granular, and near the base of the hill, towards Moel-y-Golfa, some trials have laid bare the large concretionary trap, as in this wood-cut.

49.




*a.* Schist. *b.* Amorphous trap. *b**. Concretions in the trap. *c.* Vein of calcareous spar in the schist.

At this spot it is well to observe, that a vein of pure white calcareous spar of about six feet in width, is a few paces only distant from the trap. Will the chemist permit the speculation, that this pure calcareous matter has been abstracted from the contiguous calcareous flagstone and shale by the heat which accompanied the intrusion of the trap rock? Other beds of finely laminated and indurated sandstone are thrown off in nearly vertical positions, inclosing between them portions of the same white calcareous spar. The veins (and nests) of barytes, whether in this hill or in the depression between Cefn-y-Castell and Builthy, have the same relations to the trap, or occupy the space between the intrusive rock and the tilted, broken, and often indurated strata. They consist for the most part of the sulphate, although the carbonate of barytes also appears in small quantities, with occasional strings of galena. A mass of sulphate of barytes has been previously described in a similar position on the western limits of the Corndon Hills, near Wotherton. At the great lead mines of Snailbatch, the altered schist and sandstone contains so large a quantity of sulphate and carbonate of barytes, and white calcareous spar, that the mounds of those minerals mixed with quartz, &c., thrown out upon the sides of the hill, form a conspicuous object to all the adjacent

[1] The bedded felspar breccia has recently been cut into by galleries by Mr. Ryan, for the extraction of the pure felspar rock.

parts of Shropshire. The mine of Snailbatch, it has been shown, lies upon a band of igneous eruption, and these varied and altered rocks of Wotherton, Middleton, &c. only differ from it in containing less of the more valuable ores of lead.

The previous details have shown, that the Breidden Hills, like those of Corndon and Shelve, present two classes of trap rock, the one contemporaneous with the formation of the associated shale and sandstone, the other injected after their consolidation. But at what period after the consolidation of the Silurian deposits were the chief masses of the Breidden thrown up? The evidences prove that the Silurian rocks had been first elevated to some extent before the coal-measures were accumulated, while the latter are so much dislocated as they approach these hills, that there can be no doubt that they have been also affected, though at a subsequent period, by the outburst of volcanic matter. For example, the extremity of the Shrewsbury coal-field is worked at Coed Wae, within half-a-mile of the north-eastern termination of these trappean ridges, and there the strata are so highly inclined that the workmen were obliged to board up the drifts. The exact relations, however, of this, and all other parts of the contiguous coal-field, extending in a narrow band to Pontesbury, are ill-developed, the junction between them and the various members of the Silurian System on which they rest, being much obscured by sloping accumulations of local detritus. But there are other examples of high inclination, like this of Coed Wae, and also numerous faults, some of which have been previously adverted to. Hence, although we have no positive demonstration of trap in contact with coal, as in the cases of the Clee Hills and Coalbrook Dale, we might, from such evidence alone, speculate with the highest probability on some of the eruptions of the Breidden, like those of the Wrekin, having been posterior to the formation of the coal-measures. Following up this inquiry, I will now proceed to offer other independent proofs, that volcanic action has been continued along the same line of eruption, into periods subsequent to the consolidation of the New Red Sandstone, and even of the Lias.

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### *Trap Dykes on the line of the Breiddens which have cut through the New Sandstone, explanatory of the period of certain lines of elevation and dislocation in North Shropshire and Staffordshire.*

I have previously stated that there are few geological points more difficult to define accurately than the age of trap rocks. They have frequently been described as of the age of those strata with which they are found in contact. Such distinctions, however, are altogether untenable, except where the volcanic rocks were actually evolved during the accumulation of the sedimentary deposits with which they are associated; and numerous instances of such contemporaneous traps have been already described. I

have further shown that this contemporaneous class has been afterwards broken through and dislocated by intrusive trap, and special attention is now invited to dykes which, proceeding from the Silurian System, affects also the New Red Sandstone of Shropshire. In concluding this chapter, therefore, I will describe: 1st. The trap dykes alluded to. 2ndly. The connection of these dykes with a distant mountain mass of trap rock. 3rdly. The signs of elevation and alteration perceptible in the New Red Sandstone along axes coincident with the direction of these intrusive rocks. And 4thly. It will be shown that this line of elevation serves to explain how the great outlier of Salopian Lias was dissevered from the chief mass of that formation.

In the summer of 1834, the mansion of Sir Andrew Corbet, Bart., at Acton Reynolds, eight miles north of Shrewsbury, having been subjected to a thorough repair, the ground beneath and around it was cleared to the foundations, when masses of a hard, dark rock were discovered, passing like walls through the sandstone upon which the house is built. Being informed of this circumstance[1], I visited the spot; and although at that period a great portion was covered up, sufficient was exposed to explain the nature and relations of these rocks. The part which I inspected was a dyke about four feet and a half wide, chiefly made up of concretions, which cut through the horizontal beds of sandstone from north-west to south-west. The sides of the trap were vertical, and between them and the sandstone was a thin "sahlband" or coating of decomposed felspar. The contiguous sandstone was indurated for a few inches, and contained disseminated grains of earthy oxide of manganese, but at a greater distance it had its ordinary characters. These strata belong to the central mass of the New Red Sandstone, and immediately underlie the stone of the celebrated quarries of Grins-hill, distant about one mile. (see pp. 39 *et seq.*) In its course to the south-east, this dyke in passing under the house expands to a width of eight or nine feet, and therefore the portion which I examined was possibly near its termination. A second dyke, parallel to the above, ranges beneath the western part of the house. A third and larger dyke trends from E.N.E. to W.S.W. and consequently cuts across the two parallel dykes. The point of intersection of this transverse dyke with that first described having been covered by the progress of the building, I was prevented from personally examining it; but I collected specimens which had been extracted, and as they precisely resemble the rock I saw, there can be no doubt that the small dykes running from south-east to north-west were mere branches from the large central dyke. The rock consists of two varieties: 1st. A porphyritic greenstone, consisting of a dark-coloured base of hornblende and granular felspar with white crystals of common felspar. 2ndly. A mottled, rough concretionary rock, made up of pink and dark grey compact felspar with imbedded crystals of common felspar, the concretions often assuming angular forms and thus resembling a breccia, but as they and the matrix are of similar composition the whole must be regarded as concretionary. As I was well acquainted with both these varieties of trap, having previously examined them near Welch Pool and in the Moel-y-Golfa range of the Breidden Hills, and as I perceived the direction of the principal dyke would if prolonged, terminate precisely in that range, it occurred to me that, although Acton Reynolds was fifteen miles distant from the Breiddens, these dykes might be connected with that great centre of igneous eruption. I was further disposed to adopt this view, upon observing that the chain of hills of New Red Sandstone which extended over the intermediate country offered evidences of dislocation. Further inquiry confirmed

[1] By Mr. Carline, the architect.

the accuracy of the conjecture[1]. In the previous account of the Breidden Hills, it has been shown that the trap forms two principal parallel ridges ranging from W.S.W. to E.N.E., viz. Moel-y-Golfa and its dependent hills extending to Bauseley on the S.S.E., and the Breidden, properly so called, on the N.N.W. In these ridges it has also been shown that there are evidences of two periods of eruption. 1st. Of contemporaneous trap, alternating conformably in thin bands with schists of the Silurian System. 2ndly. Of intrusive trap, which bursting through the former, has thrown the strata into vertical and dislocated positions, altering them and producing veins more or less metalliferous. Besides the Silurian rocks and bedded trap rocks affected by these eruptive masses, there are indications on the flanks of Bauseley Hill that movements of the trap have also affected, as before stated, the carboniferous strata, which there repose unconformably upon the edges of the older rocks. Proceeding to the E.N.E. in the direction of the axis, there are about five miles of country in which no rocks are visible, the valley in which the Severn flows being thickly covered with gravel and other detritus; but in the environs of Ness Cliff, hills of New Red Sandstone rise from the plain and are more or less continuous for many miles to the E.N.E., precisely in the prolongation of the axis of the Breiddens.

The axis of the Moel-y-Golfa ridge is well exposed in a small hill, six miles and three quarters west of Shrewsbury, recently cut through in lowering the Holyhead road, where strata of dark red, yellowish, and whitish red, thin-bedded sandstones are tilted 35° to the N.N.W. or at right angles to the axis. The vast accumulations of detritus of New Red Sandstone, mixed up with fragments of trap, Cambrian, Silurian, coal measure, and other rocks, which are piled up in Ensdon Hill and other localities between this line of elevation and the town of Shrewsbury, are thrown off upon the southern flank of the eruptive line. Following this line we find it preserving the true character of an anticlinal, for in the hills around Great and Little Ness, the strata of sandstone rise to the surface in dome-like forms, and after passing over a denuded tract covered with enormous accumulations of gravel, clay, and boulders[2], an unequivocal anticlinal is exhibited in Pim Hill, where the sandstone emerges from the plain and rises to a height of about 600 feet. On the northern slopes of this hill, thick beds of yellowish friable sandstone dip 25° N.N.W., whilst on the southern, or towards Shrewsbury, beds of deep red sandstone incline to the S.S.E.

But it is not merely the reversed dip which indicates the direction of the axis of elevation, for the sandstone in the central portion of the hill is so hard, white, and compact, and in so unstratified or amorphous a condition, that it has every appearance of having undergone great alteration. It is made up of fine grains of quartz, cemented by decomposed felspar, and though not altered to the same extent as the sandstones of the Silurian System which I have shown in previous chapters to have been changed into granular quartz rock, there is a close approach towards that state. This amorphous mass having been cut into for the use of the roads to the depth of forty feet, is rent by vertical fissures, the faces of which are frequently in the state of slickenside. Crystallized carbonate of lime is detected in small veins, and earthy oxide of manganese is both disseminated in grains through the mass and spread in thin films over the faces of the fissures. Stratification is perceptible only towards the sides of the quarry and near the summit, where the beds recovering their ordinary friable structure, dip to the N.N.W. and S.S.E. The whole in fact constitutes one great quartzose veinstone, running transverse to the strike of the beds, whilst numerous minor veins of similar composition cut across the strata in the adjoining slopes.

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[1] In the second visit to establish this point I was accompanied by Mr. W. Hamilton, Sec. G.S.

[2] See account of these boulders and gravel in the concluding chapters.

Though no trap is visible in Pim Hill, yet this mass of veined and altered rock lies so directly upon the axis of the trap of Moel-y-Golfa, that, independently of other proofs, this striking coincidence in range might lead to the conjecture of a connection between them. But when to this fact we add, that the principal dyke of Acton Reynolds is also precisely in this line, and three miles more distant than Pim Hill from the great source of eruption; and further that the trap of these dykes is identical in structure with that of Moel-y-Golfa, the conviction becomes irresistible that a powerful line of dislocation caused by volcanic activity acting along the same fissure has also produced the alteration of the sandstone at this point. This anticlinal line is however traceable for many miles to the E.N.E. far beyond Acton Reynolds, and usually elevates the strata "en dôme," as at Stanton and Blakeley Hills. It may, indeed, be followed into Staffordshire, passing the Birmingham and Liverpool Canal near Goldstone Common, where highly dislocated strata were observed by the Rev. Thomas Egerton precisely in the continuation of the axis above described, though at a distance of upwards of thirty miles from Bauseley Hill, or the end of the ridge of Moel-y-Golfa.

Another line of elevation in the contiguous masses of New Red Sandstone has a direction nearly parallel to the same axis. Being within a mile or two of the other it might by some be considered merely as the west-north-western face of the same line of disturbance; but when it is recollected that the Breidden Hills present two principal parallel ridges with a depression between them (see Map), the coincidence between the forms in which they have been erupted and the double lines of elevated sandstone in North Salop, is too remarkable not to lead to a belief in the community of their origin. While, therefore, the one parallel is referred to the axis of Moel-y-Golfa, the other is conceived to be due to the eruption of the Breidden or Rodney Pillar Hill. The latter axis is first marked in the bluff headlands of Ness Cliff, about a mile distant from the parallel of Moel-y-Golfa, the beds being slightly bent or arched to the N.N.W. and S.S.E.[1] There are few peculiarities in the lithological structure of these rocks, except that veins of quartz and sulphate of barytes occasionally project above the weathered and lichenized surfaces of the sandstone, generally ranging oblique to the strike of the ridge. In Broughton and Clive Hill, still further to the E.N.E., the strata contain concretions of calcareous spar, which sometimes inclose nests of green carbonate and grey copper, iron pyrites, &c.[2]; and copper ores in still greater abundance have been recently observed at Tedstill, Pradoe, near the north-western edge of the Ness Cliff Hills. Similar rocks, with veins of chalcedony, minute strings or nests of copper ore, small concretions of white and red lamellar sulphate of barytes, and blackish spots (probably ferruginous oxide of cobalt), occur in the escarpment of the Hawkstone Hills near Marchamley, where the strata dip to the N.N.W. and pass beneath the red and green marls which support the lias of Prees and Cloverly. As there is a zone of strata more or less metalliferous on this parallel, similar to that noticed in the prolongation of the Moel-y-Golfa axis, it is natural to infer that they may have been produced by the same cause. This line of elevation, or a branch of it, extends into the bolder range of hills, which, proceeding from the south of Hawkstone, passes to the north of Hod-net, and by the south side of Market Drayton, extends into Ashley Heath, Staffordshire, 800 feet above the sea, the highest point perhaps in Great Britain, occupied by the New Red Sandstone[3].

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[1] It is from this spot that the preceding view of the Breidden Hills was taken.

[2] At Broughton the calcareous matter so predominates, that the beds have been worked for lime-burning. They dip to the N.N.W. (See p. 37 *et seq.* where these beds are referred to the Muschelkalk.)

[3] I have not yet traced these lines of dislocation to their termination on the E.N.E. This examination would have led me beyond the region of the annexed map.

When measured with precision, these lines of elevation, instead of being strictly parallel, are found to diverge gradually from each other as they proceed to the E.N.E., while to the W.S.W. they converge towards the Breiddens, and finally are coincident with the fissure on which those hills were erupted. They therefore resemble the great longitudinal, fan-shaped lines of disturbance which range through the coal-field of Coal Brook Dale, proceeding from the hill of Lilleshall as a volcanic nucleus. (See pp. 110, 234, Map, and further observations following the description of the Dudley Coal-field and Lickey Hills.)

The discovery of a large elliptical basin of lias, the major axis of which is parallel to these axes, adds much interest to the case. This basin, as already described, p. 22, is flanked on the S.S.E. by the Hawkstone and Market Drayton Hills, whilst on the N.N.E. it is bounded, though at a greater distance, by another range of New Red Sandstone, which rising near Malpas, extends into the hills of Bickerton, Bulkeley, and Peckforton. This last-mentioned range of hills also slightly diverges from the main axis of the Breiddens, trending from south-west to north-east, and coincides remarkably in mineral characters with the ridges just described. Thus, at Bickerton is a mass of hard, white, compact sandstone, coated with black oxide of manganese like that of Pim Hill, and dipping to the north-west, whilst other beds of red marl and sandstone incline to the south-east; and though the prevailing dip of these hills between Beeston and Bickerton is to the south-east, there is a transverse disruption in the central part (Peckforton and Bulkeley) where the strata are thrown over to the N.W. and W.N.W. On the south-eastern face of the Peckforton Hills, copper ores have been extracted to a small extent. These ores occur in strings and veins associated with dislocations more or less transverse to the main direction of the red sandstone, the only exception with which I am acquainted being in Stanner Hill, where certain poor mineral veins appear to range from south-west to north-east, or parallel to the ridge. Sulphate of barytes is not unfrequent, and Sir Philip Egerton informs me that it is frequently disseminated through the sandstone.

From the undisturbed position of the lias between the two fan-shaped lines of elevation, which threw up the New Red Sandstone of the Hawkstone Hills on the one side, and the Peckforton on the other, it may be inferred that eruptive forces have destroyed an overlying mass of that formation which may have once extended so far towards the south-east, as to connect this outlier with the main escarpment of the formation, while the intervening region was left in a tranquil state; and thus the preservation of this singular outlier is satisfactorily explained.

We shall afterwards extend this inquiry and apply the same tests to other districts, particularly to the red sandstone surrounding the great coal-field of Dudley and Wolverhampton, and extending to the south of the Lickey Hills, with the view of determining the periods at which such tracts have been disturbed; and we shall again show that great periods of dislocation took place posterior to the lias, on lines of ancient eruption.

In the meantime, by completing the observations in one region, it has been proved, that volcanic matter was emitted for a very long time during the formation of the Silurian strata, and that afterwards other eruptions took place, throwing those ancient strata into vertical, undulating, and broken masses, and probably giving rise to metalliferous veins; that the coal measures were accumulated after the last-mentioned period of disturbance, because they rest unconformably upon the inclined edges of the Silurian rocks; and lastly, that other volcanic forces, evolving products similar in lithological structure to those previously erupted, renewed their activity on the same lines of fissure after the accumulation of the New Red Sandstone and even of the Lias.

# CHAPTER XXIV.

*Range and Distribution of the Silurian Rocks in Montgomeryshire and the adjacent Districts of Shropshire and Denbighshire.* (Pl. 32. figs. 1, 2, and 9. Pl. 33. f. 1.)

IN the three preceding chapters it has been shown, that the Longmynd and adjacent hills constitute a mineral axis, in which certain rocks of the Cambrian System throw off the Silurian deposits on their flanks; that the Silurian rocks to the west of this axis have been the theatre of intense volcanic action and are the seat of valuable mines; and that the Breidden Hills, still further to the west, have been formed by another outburst of volcanic matter. Having attempted to fix the æras of these eruptions, and to explain the effects they have produced upon the sedimentary deposits, I now proceed to the consideration of the strata composing the Silurian System which are spread over the south-western parts of Salop and wide tracts of Montgomeryshire and Denbighshire. We shall thus complete the account of these deposits over one large district before we follow them into South Wales.

The Silurian strata which occupy this large tract, lie in several undulations or troughs, between the districts already described and the Berwyn Mountains, constituting in fact a number of parallel anticlinal and synclinal lines. (See transverse section, Pl. 32. f. 9.) The Ludlow Rocks, properly so called, extend over a large portion of the eastern side of this area. In the environs of Clun and Bishop's Castle, they occupy the hills of Clunbury, the Black Mountain, &c., and sweeping round by Stow Hill to Knighton, they support the great detached outlier of Old Red Sandstone of Clun Forest, forming Kerry Hill on the west, and on the north and north-east the hills of Bishop's Castle, Walcot Park, Eyton and Bury Ditches. (Pl. 33. f. 1.) Wherever the Silurian rocks are near the Old Red Sandstone, as at Clun, they consist of the true Upper Ludlow Rock, characterized by *Homalonotus Knightii*, *Serpuloides longissima*, *Leptæna lata*, *Orbicula rugata*, *Cypricardia amygdalina*, *Orthoceratites*, and other well-known fossils, and have precisely the same mineral characters as the rock in the immediate vicinity of Ludlow, being also quarried for the same purposes. In this range they vary in height from 800 to 1400 feet, the strata upon the whole dipping inwards, and forming

the elevated trough, in the centre of which lies the Old Red Sandstone of the forest of Clun. Though the junction of these rocks with the Old Red Sandstone is clearly defined, it is not practicable to trace through these mountains the same subdivisions of the strata as in the Ludlow district, there being no good representative of the Aymestry Limestone, nor a trace of its beautiful fossils. Receding from the limits of the Upper Ludlow Rock, we see in numberless well-defined and open sections a succession of inferior strata, which conduct us downwards to well-marked Lower Ludlow Rocks, without the intervention of a single bed of limestone, however impure. We occasionally meet, however, with a narrow band, filled with the *Terebratula Navicula*, which may be considered to *represent* the Aymestry Limestone.

Some of the harder beds of the Lower Ludlow are quarried for flagstones in Kerry Hill and at Yechad, where they contain two species of *Cardiola* and numerous *Graptolites*, fossils already described as characteristic of this subdivision, but which have never yet been observed in the Upper Ludlow Rock. The same beds are quite as clearly exhibited on the eastern side of Clun Forest, in the lower parts of the Black Hill, &c. (The greenstone of the inhabitants.) We can thus clearly define both the Upper and Lower Ludlow Rocks in that portion of the tract in which they pass upwards into the Old Red Sandstone.

Ludlow rocks, containing the same fossils, occupy nearly all the higher parts of the Long Mountain (1330 feet) between the Corndon and the Breiddens, though the Upper Ludlow Rock is ill developed. (See Pl. 32. f. 2.) Below that zone, which is marked by the flagstones containing the *Cardiolæ*, is a badly defined succession of strata, for owing to the absence of any representative of the Wenlock limestone it is impracticable to separate the strata underlying the flagstones from those above them, and to decide, that this portion of shale belongs to the Ludlow, that to the Wenlock formation. We are here, therefore, compelled to include both formations under the comprehensive term of Upper Silurian Rocks; and *the same absence of limestone and fossils obliges us to apply this broad classification to large tracts in North and South Wales.*

The whole of the strata in the valley of the Severn from Newtown to the Breiddens are of this age. They surround the town of Montgomery, and extend in undulating masses from Newtown to Llanfair, and are admirably exhibited in the valley of the Berriew. They form all the ridges of the beautiful upper park of Powis Castle, and are admirably laid open in the hill of Yr-Alt, N.N.E. of Welch Pool. They are also repeated in troughs at Meifod, between the valleys of the Severn and the Ffyrnwy[1], these troughs being bounded by ridges of the inferior Caradoc sandstone. (Pl. 32. f. 9.) The Upper Ludlow is wanting throughout the greater part of this range, and the prevailing rocks have the incoherent character of the Lower Ludlow and Wenlock shales. As the strata of these hills are thrown over with reversed dips, they can be examined in numberless sections. The whole of the Long Mountain is a trough-shaped elevation, the flagstones and lower shales rising on all sides towards the flanks of the mountain. (Pl. 32. f. 2.) On the western slopes, near Nelly Andrew's Green and Gaithley, the lower argillaceous strata being near the volcanic range of the

[1] The English reader may be informed that the Welsh name of this river, Ffyrnwy, though apparently so unpronounceable, has the agreeable and mellifluous sound of *vernew*.

Breidden Hills are thrown off at the high angle of 70°, dipping to the south-east, under thin, flaggy, argillaceous and slightly micaceous sandstone, containing *Cardiolæ, Orthocera,* and *Graptolites;* and on the opposite side of the mountain, at Roughleigh, the same beds dip to the north-west, though at a much lower angle. The slighter inclination of these strata is explained by their being so much further from the trappean axis of the Corndon. (See the last chapter.) In the central or highest parts, as for example near the Harp, the beds are very little inclined.

In Powis Castle Park, and in all the ridges between it and the junction of the Berriew and the Severn dull grey shale prevails, occasionally enclosing spherical concretions, the whole being undistinguishable from the Lower Ludlow Rock and Wenlock Shale in many other localities. The concretions consist of impure black argillaceous limestone, varying in diameter from four inches to a foot, and break with a conchoidal fracture, in which respect, and in containing strings of white and black calcareous spar, they resemble the septaria of the London clay or the nodular cement stones of the Lias. The nucleus of these concretions consists sometimes of calcareous spar, quartz crystals, carbonate of copper, with occasionally minute nests and flakes of anthracite. Other concretions are formed around organic remains, as the *Asaphus caudatus, Calymene Blumenbachii, Orthocera,* &c.; and when the natural divisions of these organic remains are occupied by any of the above simple materials, they are beautifully diversified[1]. The bands of argillaceous sandstone which lie in the troughs between the valleys of the Severn and Ffyrnwy (see section, Pl. 32. f. 9.) present nothing remarkable; and the hill of Yr-Alt may serve as a sample of the whole. Occasionally they produce a flagstone, which is durable if not exposed to the atmosphere. The quarries on the south-eastern face of Golfa Hill, and those in the western sides of Powis Castle and in the bed of the Berriew river near its junction with the Severn, are among the best examples, the stone being usually of a dark indigo grey colour, sometimes slightly calcareous, and frequently marked by white veins of carbonate of lime and quartz. The varied inclination of the strata composing the chief masses of these "mudstones" in Montgomeryshire and the adjoining parts of Salop will be best understood by reference to the map and sections, the dip being of course usually highest near to those anticlinal lines along which the inferior strata are thrown up in numerous parallel ridges. (Pl. 32. f. 9.)

### *Lower Silurian Rocks, or Caradoc Sandstone, and Llandeilo Flags of West Salop and Montgomery.*

The Lower Silurian Rocks to the west of the Longmynd are prominently exposed in the upland district of Shelve and Corndon, where they have been described as alternating with ridges of trap rock (Chapter 22.). Many of these ridges consist of the Caradoc sandstone, others of flagstones similar to those at Llandeilo. The uppermost members of these Lower Silurian Rocks in the form of impure sandy limestones, like those described p. 217., containing the *Pentamerus oblongus, Productus sericeus,* and other well-known fossils, fold round the highly-inclined edges of the older Cambrian rocks of the Longmynd or oldest mineral axis of Shropshire. Examples are seen

[1] Similar concretions are characteristic of the Lower Ludlow Rock in the neighbourhood of Ludlow and Aymestry, near Elton, and also on the flanks of Deerfold Chase. (See p. 205.)


VIEW OF BREIDDIN HILLS, FROM POWIS CASTLE.

C. Murchison delt. Day & Haghe Lithrs.

near Linley Hall, extending thence by Norbury to Wentnor, and at Cox's Mill. This unconformable arrangement is of great interest in teaching us, that where those strata which in other places form the beds of passage between the Silurian and Cambrian systems are wanting, the contiguous rocks belonging to the two systems are unconformable; and it also seems to prove, that such Cambrian rocks had been placed in inclined positions, before the deposition of the Caradoc sandstone had commenced.

At the north-western edges of the Long Mountain, between the Black Moor and the Ffron Gate, are red and green sandy shales, containing the same species of Lingula as the shale at Buildwas. These red and green beds so contiguous to the coal-field of Shrewsbury might well be mistaken for the Old Red Sandstone; but the included organic remains and the dip of the strata beneath beds inclosing fossils of the Wenlock shale completely decide the case. On the south-western flanks of the Long Mountain is not only the usual thick development of Upper Silurian Rocks, namely, a flag-like mudstone with a lower shale containing concretions of argillaceous limestone, but also thick-bedded, hard, and greyish blue grits, wrought into square blocks of good and durable quality. These, on exposure, frequently become of a rusty brown colour. Judging from their mineral character, I am disposed to place these grits in the Caradoc formation.

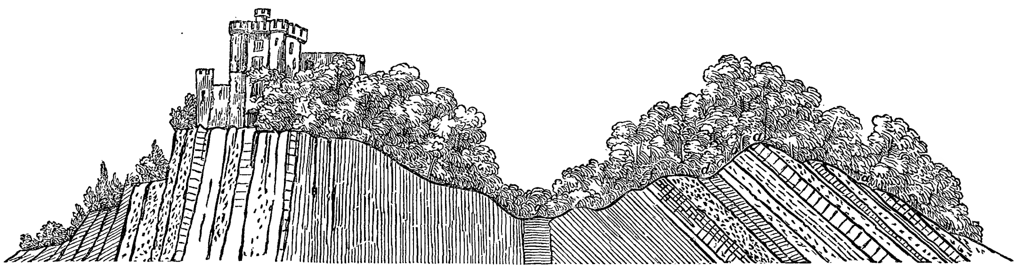
Beds of calcareous sandstone, with fossils similar to those on the eastern flanks of the Caradoc, occur at the Cefn near the flank of the Breidden Hills, where they are penetrated by trap rocks. (See last chapter, p. 293.)

Another zone of these deposits is thrown up at Welch Pool through the Upper Silurian Rocks, and extends from about a mile N.N.E. of that town to upwards of a mile S.S.W. of it. These are upon the line of a trappean eruption before described (the Breidden, Standard, &c.). The Caradoc sandstones in this short range are of red and dark grey colour, the former predominating. In the high ground north of Welch Pool, called the Red Hill, are quarries in highly inclined and fractured strata of these rocks, some of them consisting of hard grits, in parts calcareous, others of mottled, red and grey sandy shale, the former predominating. In a woody dingle[1] between these old quarries and the Standard or great trap dyke, the shale abounds with casts of beautifully ornamented trilobites of the genus *Trinucleus*, so abundant in the Caradoc sandstone of other tracts. Some of the more calcareous beds are seen on the flanks of the Standard trap dyke, and they again protrude in various detached masses in the park of Powis Castle. One of these, near the north end of the park, is a grey, impure, sandy limestone, in parts concretionary, the weathered surfaces of the concretions being marked by shells, corals, &c. But the most remarkable of these knolls is that on which Powis Castle is built, the edifice having been constructed from quarries in

[1] As this ravine had not, as far as I could ascertain, any name, I venture to hope that, to mark so interesting a fossil locality, Lord Clive will call it "Trilobite Dingle." The large specimen, *Asaphus Powisii*, named in honour of the noble family, so justly beloved throughout Montgomeryshire, was found at this spot with the *Orthis testudinaria* and other shells, and two or three species of the genus *Trinucleus*, including *T. Caractacus*. (See description of these trilobites in the chapters on Organic Remains.)

another parallel, contiguous mass[1]. The rock beneath the castle is a red grit, in parts so calcareous and highly charged with portions of encrinital stems as to constitute an impure limestone. The faces of these beds are well exposed as massive buttresses in the hanging garden-terraces, where, being nearly vertical or inclined at angles of 70° to 80° to the E.S.E., they have the appearance of forming the lower walls of the noble building. Between this rock and the lower ridge upon the west, the carriage road passes through a depression, which is probably on the line of a fault, for upon reaching the quarries we find the strata in a parallel ridge dipping to W.N.W. 45°. These relations will be understood by inspecting this wood-cut.

50.



Garden terraces. Castle rock. Road and fault. Old quarries.

The character of the strata varies much, even in a very short distance; but in a transverse section made near the south end, the quarries present in descending order:

| | | Feet. |
|---|---|---|
| *a.* | Purplish brown, calcareous grit, with many fragments of encrinites, in beds from eight inches to one foot and a half, with way-boards of red shale, in parts a sandy and gritty, in others an encrinital, subcrystalline limestone (see wood-cut) | 20 |
| *b.* | Blotchy grit with much red shale | 5 |
| *c.* | Hard, fine-grained, calcareous grit, passing downwards into a mottled, dingy green, and purple impure limestone with irregular traces of way-boards | 6 |
| *d.* | Purple and white limestone with blotches of red shale | 4 |
| *e.* | Hard, fine, thick-bedded, calcareous conglomerate, red where weathered, but greyish where freshly broken. It consists of fragments of encrinites, green earth, chocolate-coloured schist, and a few quartz pebbles, of sizes varying from almonds to small peas | 6 |
| *f.* | The lowest bed visible is a purple and whitish, semi-crystalline limestone with white veins | 3 |

So numerous are the dislocations at this spot, and indeed through every part of the park, that these beds can be traced continuously for only a few paces to the north-east, when they are thrown back into another low ledge, the strata of which dip 70° to the N.N.W. In this the prevailing colour is grey, and at the extremity of the quarries, the beds pass into concretionary, subcrystalline, hard, impure, mottled limestone. Where these rocks do not form separate knolls, their course is marked by the red roads or red land produced by the decomposition of the beds extending from Welch Pool through Powis Castle Park, to the Red Lane, where the axis subsides.

[1] Some idea of the beauty of this scene may be formed from the sketch prefixed to this chapter. It is taken from Powis Castle looking to the Breiddens, and presents almost the same outline as a coloured drawing by Lady Lucy Clive. The name of the castle in Welsh is Castel-coch or goch (Red Castle).

Separated from the zone of Welch Pool by the flags and mudstone of the intervening ridge of Golfa and its dependencies, is another low elevation of red rock near the Quakers' burial ground. It is composed of slightly micaceous and argillaceous red sandstone, overlaid by slightly calcareous beds and quartzose red conglomerate, fine-grained purple grit, and flag-like sandstone, containing portions of trilobites (*Trinucleus*) and rounded impressions of stems of encrinites, precisely like those of the Caradoc sandstone. The pebbles are quartz, varying in size from hens' eggs to beans, and the matrix is calcareous; the beds being separated by thin courses of red spotted shale and calcareous concretions of red, green and purple colours. These beds dip 45° to the N.N.W. and are traversed by a number of joints. The line of this elevation of the lower rocks is indistinctly traceable to the north-east into the high road between Garth and Welch Pool. It is met abruptly by a much higher elevation of similar rock in the hill of Moel-y-Garth (860 feet above the sea), the direction of which is *transverse to that of all the ridges of this district*, being nearly north-west of south-east[1]. The structure of this remarkable hill is well exposed in different quarries on its south-western face, where the beds dip away to the W.S.W. at angles varying from 40° to 60° and consist of flaggy, grey sandstone and shale, hard, purple conglomerate grit and sandstone, greenish and brownish, slightly micaceous, grey sandstone, &c. In these beds are casts of the large *Orthis expansa*, Pl. 20. f. 14, and other shells, with encrinital stems. The rocks of the Moel-y-Garth have a tendency to slaty cleavage, the laminæ in one part being nearly vertical, and ranging from 10° east of south to 10° west of north. In quarries near the summit of the hill the brownish hard sandstone is split by joints into parallelopipeds, the surface of the beds being covered with black and purplish blue oxide of iron and some thin pellicles of shale. Beyond the north-western extremity of Moel-y-Garth, the strata resume the prevailing strike of the country, and red rocks of the Caradoc sandstone, occupying hillocks at Hendrechen, range to the north-east by Croes-wood to Gaerfawr, where they attain the height of 754 feet.

Gaerfawr[2], though of no great altitude, is a very striking object, for as it is the last hill of any note upon this parallel, it impends over the flat valley of the Severn. An excellent transverse section of a portion of the Caradoc sandstone is seen in a gorge passing from the valley of Guilsfield to the north-west of Gaerfawr. The strata dip to the west and north-west, at angles which are highest near Guilsfield and decrease in the overlying strata, which succeed each other in the following *ascending* order:

1. Argillaceous, sandy shale. 2. Thin-bedded, highly micaceous, hard sandstone, splitting into rhombic fragments, with casts of shells on the surfaces of the beds. 3. The same sandstone with casts of shells marked by yellow hydrate of iron; beds four inches to one foot. 4. Thick beds of calcareous grit, passing upwards into a light grey impure limestone with fossils: forty or fifty feet of this rock are exposed in one quarry, the beds dipping from 40° to 35° to the north-west, but only the three or four feet of the uppermost stratum are calcareous. 5. Grey shelly sandstones form the western and north-western slopes of the Gaerfawr, with some courses of sandy shale and two bands, at least, of dark indigo, subcrystalline limestone.

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[1] Lord Clive informed me that owing to this transverse direction Moel-y-Garth is called in Welch the Headland of Powis, being in fact laid athwart the other ridges. (See Map.)

[2] Impure limestone, forming part of the Caradoc formation and similar to the rock of Gaerfawr, is well laid open in quarries at the north-western foot of Moel-y-Garth, where in my last visit (Oct. 1836) I observed several convoluted fossil forms with which I was not familiar, but was unprovided with a sufficiently heavy hammer to extract them. I recommend this quarry to the attention of the fossilist; it lies about one mile south and by west of Guilsfield.

The shells most abundant here, are *Orthis expansa, O. testudinaria, O. bilobata, O. canalis, &c.* These latter beds with shale (near a spot called the Gryfin) pass at an angle of 20° under variegated conglomerate, composed of quartz, slate, hornstone, &c., the fragments varying in size from pins' heads to a man's fist. The strata, like those of the Moel-y-Garth, are traversed by joints which cut through the quartz pebbles, and their fractured surfaces have often a high degree of polish. This red conglomerate, overlying the whole system of the grey sandstones of the Gaerfawr, proves that the similar red conglomerate and gritty beds of Welch Pool, Powis Castle, the Quakers' burial-ground, and other places which rise from beneath the overlying mudstones or Upper Silurian rocks, form the upper strata of the Caradoc sandstone or Lower Silurian Rocks. The conglomerate beds passing into grits more or less red and occasionally calcareous, may be followed from the north-western flank of the Gaerfawr for about half a mile to the north-east and about two miles to the south-west, the grey and calcareous sandstones uniformly rising from beneath them. If the transverse section from the ridge of Gaerfawr to the north-west be continued, we pass over about three miles of undulating country and hilly grounds, from 700 to 900 feet above the sea, the whole composed of the mudstone or Upper Silurian Rock, before we reach the beautiful vale of Meifod, watered by the Fyrnwy, on the left bank of which are numerous ridges of Caradoc sandstone.

This formation now begins to assume even more importance than on the flanks of Caer Caradoc; for from the banks of the Fyrnwy to those of the Tanat it occupies the whole region. The first ridge is marked by its sharp and narrow form. The highest part, or north-eastern end, called Alt-y-maen, is 1160 feet; Galt-yr-Ankr, its south-western, is 740 feet above the sea; the strata of the former dipping at an angle of 70°, those of the latter 60° to the south-east. The direction of this ridge is therefore parallel to that of Gaerfawr, or in other words the valley of the Fyrnwy is parallel to that of the Severn. These inclined strata of Caradoc sandstone are slightly micaceous and occasionally calcareous, of grey and brownish grey colours externally, but dark bluish grey when cut into. They are filled with the characteristic fossils, viz., *Orthis bilobata*, Pl. 19. f. 7.; *O. testudinaria*, Pl. 20. f. 9.; *O. alternata*, Pl. 19. f. 6.; *O. expansa*, Pl. 20. f. 19.; *O. Pecten*, Pl. 21. f. 9.; and many fragments of trilobites of the genus *Trinucleus*. The shelly matter having in general disintegrated, the impression only is left in sandy ferruginous cavities. The fossils are usually arranged in irregular layers, but they sometimes pass into large sub-concretionary spherical masses. In detailing the structure of this country we must remind the reader, that to the east of the Fyrnwy, the Caradoc sandstone is thrown up only at intervals, along different axes of elevation, for the most part parallel, leaving between them troughs filled with undulating masses of the younger deposits. (See Pl. 32. f. 9.) In proportion as examination is extended to the north-west, the older strata are repeated with much greater frequency in the numerous parallel ridges lying between the Vale of Meifod and the south-eastern flanks of the Berwyn Mountains. At the south-western extremity of the Meifod Ridge (Galt-yr-ankr) the strata bend round from their south-easterly inclination and dip, first to the west and afterwards to the north-west, and thus beds of nearly the same age are repeated in each of the sharp ridges on the banks of the Tanat, as in those which

approach to the south-eastern face of the Berwyns, the section across them exhibiting a number of anticlinal and synclinal lines.

The structure of the tract between the Ffyrnwy, and the Taunat, as explained above, and in the section (Pl. 32. f. 9.) was pointed out to me by Professor Sedgwick. To determine the boundary line between the Cambrian and Silurian Systems, he led me to the flanks of the Berwyns, and on the banks of the Iurch, a tributary of the Taunat, we observed that the rocky gorge called Craig-y-glyn and the ridge[1] of Mynidd-mawr were composed of Lower Silurian Rocks. These strata dip to the S.E., beneath the Caradoc Sandstone, and repose upon the more ancient rocks of the Berwyn chain. (Pl. 33. f. 9.) They consist of blueish and dark grey calcareous flagstones, slightly micaceous, passing into earthy limestone and also into sandstone. Joints of encrinites abound in the limestone, and casts of them in the sandstone. The most interesting fossil, however, is the *Asaphus Buchii*. It has before been stated, that this crustacean characterizes the Llandeilo flags ; a formation well defined by its mineral and zoological characters. The clear evidence of the relative antiquity of these beds was therefore a subject of great satisfaction ; particularly as it proved, that however great and frequent might be the lines of disturbance in this region, occasioning many breaks and powerful undulations ; still the strata had progressively increased in thickness from south-east to north-west, exhibiting a fulness and clearness of succession, which it was very important to point out, in the history of such ancient deposits.

These fossil beds are affected by slaty cleavage like those of the Moel-y-garth, but to a much greater degree. They dip from 15° to 25° to the south-east, the inclination decreasing towards the valley of the Tanat. The lines of true bedding could with difficulty be traced if the rock were not fossiliferous, but the trilobites, encrinites, and other organic remains, including the *Orthis protensa*, (Pl. 22. f. 8. 9.) mark the laminæ of deposition. The other lines which obscure the true stratification are two-fold. 1st. Innumerable lines of cleavage, which cross the beds at high angles, dipping 70° north-west : these are all precisely parallel to each other, the cleavage passing directly through the bodies of organic remains, pebbles, and concretions. 2ndly. Joints, nearly vertical, more or less irregular, which are several feet apart.

Veins containing lead ore, penetrate the flagstones, and are more or less abundant along the eastern flanks of the Berwyn chain. As persons unaccustomed to work in countries where the strata have the slaty impress, would have difficulty in distinguishing the true dip from joints and planes of cleavage, I refer them to the writings of Professor Sedgwick, who first clearly drew the distinction, and to the diagrams pp. 359, 360, 393, and 400, explanatory of the structure of similar rocks in Caermarthenshire and Pembrokeshire[2].

[1] *Cader Ferwyn* is 2715 feet above the level of the sea. These lower ridges are about three miles north of Llanrhaiadr, and rather more distant from the celebrated and striking waterfall of Pistill Rhaidyr. (See Map.)

[2] In this example the position of the organic remains removes all doubt in distinguishing the laminæ or deposit from the planes of cleavage. In those rocks where organic remains are absent, Professor Sedgwick has taught us, that we may generally conclude that the great lines of cleavage which affect a whole mountain,

The structure of the Berwyn Mountains, which form the upper portion of the great Cambrian System, as well as all the rocks to the north and west of them, will be fully described by Professor Sedgwick; but having traversed these mountains, in company with him, I may be permitted to state, that they mainly consist of coarse slaty rocks. Their overlying masses contain a few impure calcareous courses with casts of fossils, and at intervals thick and massive bands of porphyritic trap as well as thinly laminated, yellowish green bands of compact felspar and other rocks of igneous origin. On their north-western face, these mountains are flanked and underlaid by lower ridges of other slaty rocks, containing many massive beds and elongated concretions of dark grey limestone, some crystalline, others earthy and impure, in thickness of 10, 12, and 20 feet. In the hills east of Bala these limestones are pretty extensively quarried, and clearly dip under the chief mass of the Berwyns. Among the fossils, including those of the Bala limestone, the following occur: *Orthis anomala*, Schlot. Pl. 21. f. 10.; *O. Actoniæ*, Pl. 20. f. 16.; *O. canalis*, Pl. 20. f. 8.; *O. compressa*, Pl. 22. f. 12.; *O. Flabellulum*, Pl. 21. f. 8. (a); *O. lata*, Pl. 22. f. 10.; *O. Pecten*, Dalm.? Pl. 21. f. 9.; *O. protensa*, Pl. 22. f. 8. 9.; *O. testudinaria*, Dalm. Pl. 20. f. 9.; *Bellerophon bilobatus*, Pl. 19. f. 13.; *Leptæna sericea*, Pl. 19. f. 1, 2.; *with two or three unpublished species.*

As these shells abound also in the Lower Silurian Rocks, it would seem that as yet no defined line of zoological division can be drawn between the Lower Silurian and Upper Cambrian groups, and that as our knowledge extends, we may probably fix the lowest limit of the Silurian System beneath the line of demarcation which has for the present been assumed. In the meantime, transitions which, like this, are clearly marked by stratigraphical, lithological, and zoological proofs, are of the highest value in establishing the true classification of sedimentary deposits. Though frequent in the overlying formations, as developed in the previous chapters, they are necessarily of rarer occurrence among the oldest fossiliferous strata, owing to the greater number of convulsions and changes, which they have usually undergone, and hence the geological value of this section. In Caermarthenshire, similar passages will be pointed out; but in that region, the beds in question are neither so largely developed, nor so much charged with fossils as near the Berwyns. To what extent the same species of shells which characterize the Lower Silurian rocks, descend into the Cambrian System, is not yet satisfactorily determined; nor can it be so, until the oldest fossiliferous rocks of Cumberland, Wales, and Devonshire are brought into close comparison, and their specific contents accurately determined[1].

In the accompanying map it will be perceived, that wherever the Lower Silurian rocks pass into the Upper Cambrian, as on the flanks of the Berwyns and in certain

running in planes mathematically parallel to each other, are *not* the laminæ of deposit. The latter have indeed always more irregular and uneven surfaces, which are frequently to be traced by decomposing edges or furrows on the weathered sides or joints of the rocks, often filled by patches of moss and grass. (See Sedgwick on slaty cleavage, Geol. Trans. vol. 3, p. 460.)

[1] Professor Sedgwick's works on Cumberland and North Wales, as well as a joint memoir by him and myself on the older Rocks of Devonshire, will, it is hoped, in a great measure, clear up this point.

parts of Caermarthenshire, the colours indicative of these formations are not very dissimilar; while in all the tracts where there is abrupt collocation of masses of different age, the intermediate strata being omitted, the boundary is rigorously defined by strongly contrasted colours.

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### *Dislocations along the Boundary between the Silurian and Cambrian Systems.*

I have said that a transition from the Silurian into the Cambrian System is rarely to be detected. This is clearly proved by passing from the Berwyns northwards into Denbighshire, or southwards into Radnorshire, for we then see that all simplicity and clearness of succession vanish. Powerful lines of disturbance mark the frontier; on one side of which are certain members of the Silurian System (seldom even the lower group), on the other old slaty rocks of the Cambrian System. Examples of such relations may be observed along the flexuous demarcation extending from the Berwyns to Moel-ben-tyrch. (see Map.) A traverse to this last-mentioned mountain from Llanfair, five miles east of it, exhibits a space watered by the river Einion and occupied by grey, *graptolite* schist, in vertical and undulating beds, with a strike varying from north-east and south-west to N.N.E. and S.S.W. Large portions of this tract are denuded and covered with coarse detritus derived from the mountains on the west. I consider those schists to belong to the lowest members of the Upper Silurian rocks which have been mentioned as undulating throughout a wide area between Welch Pool and Newtown. This region of mudstone is bounded on the west by a chain of rocks of very different composition, which ranges from Moel-ben-tyrch to near Llanwnnog, six miles west of Newtown, and is thence prolonged into Radnorshire in the mountains south of Penstrowed. The prevailing rocks in these wild tracts is a hard, quartzose, slaty sandstone, passing into a coarse grit (the greywacke of foreign geologists) usually of grey, but sometimes of purplish, brown, and ferruginous colours. In Moel-ben-tyrch I detected casts of encrinites and corals in this rock, but in general it is void of fossils, and lithologically unlike all the strata described, except certain grits and sandstones of the Longmynd in Shropshire. There is, therefore, no doubt that it belongs to the Cambrian System, and that it is of higher antiquity than the fossiliferous strata on the eastern flank of the Berwyns. Along this line of separation the absolute contact of the Silurian and Cambrian rocks is rarely discernible, owing to the vast accumulations of detritus above alluded to, but on ascending the older chain a startling phenomenon presents itself. Instead of *rising* to the north-west in their regular order, these older rocks *usually dip*

*north-west*, and have thus the appearance of being in a position overlying the younger deposits[1].

This inverted position, which is traceable at intervals for a great distance, has doubtless arisen from the intensity with which the Welsh Mountains have been dislocated. Surprising as this phenomenon may appear to those who have not studied geology, it is not without parallel in other mountain chains. I have myself observed it on the northern face of the Eastern Alps, where the newest secondary deposits are broken off by enormous faults and dip under the oldest rocks in the centre of the chain; and even in this country, inversions similar to these will be specially adverted to and their causes explained in a subsequent chapter on the Malvern and Abberley Hills[2].

[1] The dip at Moel-ben-tyrch is N.N.W. (See chapter 31, on the Abberley and Malvern Hills.)

[2] The sheets of the Ordnance Survey relating to it were not published when I first examined this tract, and therefore I do not profess to have laid down with minute precision the boundary line between the Silurian and Cambrian Systems throughout Denbighshire and Montgomeryshire. In the northern part, indeed, I have depended chiefly on the assistance of Professor Sedgwick. At Moel-ben-tyrch, however, and at the Berwyns, the demarcation is, I trust, accurate. To render the outlines more accurate, I now avail myself of the issue of two new quarter sheets of the Ordnance Survey to visit the tract again, while these pages are passing through the press.—August 19, 1837.

Hanter Hill. Worsel Wood. Hergest Ridge. Stanner Rocks.

Ince del: Day & Haghe Zinc.

## CHAPTER XXV.

### SILURIAN, CAMBRIAN, AND TRAP ROCKS IN RADNORSHIRE.

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*Upper and Lower Silurian Rocks of Presteign, the Vale of Radnor, Radnor Forest, &c.—Cambrian Rocks in West Radnor.—Volcanic Group and Altered Rocks of Old Radnor.* (Pl. 33. figs. 1, 2, 3, and 4.)

QUITTING the region where the best types of the Silurian System are exhibited, let us now follow these rocks upon their strike from north-east to south-west, through the counties of Radnor, Brecknock, and Caermarthen, till we take leave of them in the coast-cliffs of Pembrokeshire.

In this long course of one hundred and fifty miles, I shall successively direct attention to the prominent features of the system in each district, indicating specially those places where the distinguishing rocks disappear and re-appear.

We shall afterwards trace them wherever they rise from beneath the younger deposits on the eastern side of Herefordshire, and in Gloucestershire, Worcestershire, and Staffordshire.

*Ludlow Rocks on the South-eastern side of Radnorshire.*—The Ludlow rocks between Aymestry and Presteign occupy the ridge of Shobdon Hill and Wapley Court, but the central band of limestone, containing the *Pentamerus Knightii,* is no longer visible; so that the Upper Ludlow is separable from the Lower only, by observing the fossils peculiar to each, or by the harder stony character of the former, as distinguished from the perishable, argillaceous structure of the latter. Thus united, the Ludlow rocks fold round the north and west sides of Presteign, passing under the detached outlier of Old Red Sandstone at Norton; the upper Ludlow rock, as quarried at many places, being usually charged with the same shells as in the Ludlow district. (See various quarries around Presteign.) Instructive and clear sections of the Ludlow rocks are again displayed in the prominent ridge extending from the beautiful high grounds of Eyewood Park by Bradnor and Hergest Hills, north-west of Kington, the strata dipping to the south-east at low angles beneath the Old Red Sandstone. (Pl. 33. f. 2.) There are numerous quarries, both in the eastern face and in the abrupt western escarpment of these hills, and the beds abound with the usual fossils or their casts. In the excavations of Bradnor Hill above Kington, many of the beds are highly calcareous, in consequence of the shelly matter of these fossils, particularly *Leptæna lata, Cypricardia amygdalina, Spirifer ptychodes* (Dalman), *Orbicula rugata, Orthis lunata,* &c. These beds

are overlaid on the face of the hills by courses of thin-bedded building-stone similar to that at Downton Castle. On the whole these rocks are rather more micaceous than at Ludlow.

The Lower Ludlow Rock is well seen in a transverse section north-west from Bradnor to Herrock Hill, on the sides of which dull, dark-coloured, thinly laminated shale, without mica, and containing nodules of argillaceous limestone, dips under the harder strata of Bradnor Hill.

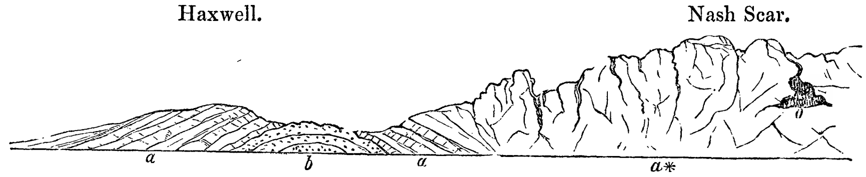
The Upper Ludlow Rock is again seen all along the Hergest ridge, and thence by Gladestrey to Pain's Castle, where the formation is strikingly displayed filled with well-preserved fossils, and overlaid by ridges of Old Red Sandstone. In no portion of the region examined are the relations of the Ludlow rocks to the overlying system more clearly shown than between Pain's Castle and the Wye. The Old Red Sandstone occupying the Clyro and Begwn Hills is succeeded on the north-west by a series of lower terraces of Ludlow rock, the beds of which all dip conformably beneath and graduate upwards into the Old Red. This "terrace under terrace" is beautifully marked near Pain's Castle at the escarpment of the Begwn Hills, and extending thence by Llanstephen to the Trewerne hills on the left bank of the Wye. It was here that I first observed a passage downwards from the Old Red Sandstone into these older formations, as represented Pl. 31. f. 1. The beds are rich in organic remains. Among the usual and characteristic fossils, the small *Pleurotomaria Corallii* occurs, surrounded by the same species of coral which envelops the shell at Ludlow, Delbury, Larden, Botville, &c., in Shropshire. The strata dip at low angles to the north-east.

In the immediate vicinity of the Begwm Hills, the lower part of the Ludlow formation has been violently contorted, especially in the narrow mountain gorge in which the Bach-Howey (Brach-Wye, or tributary of the Wye,) falls over a vertical cliff at Craig-pwl-du. These contortions being among the most remarkable to which this formation has been subjected, a sketch is annexed.

51.

*Course of the Wenlock Limestone in Radnorshire.*

Between the limestone of the undulating hills of Lingen and the next point where that rock re-appears to the south-west, is the broad denudation around Presteign; but to the south-east of the town rises a sharp low ridge extending into the Nash Scar. On the north and south-east this ridge is flanked by a limestone identical in position and organic remains with that of Wenlock. Another depression succeeds to the south-west of this ridge, and the limestone is again lost, but it re-appears on the flanks of the trap hills of Old Radnor. There the band of Wenlock limestone is much broken, contorted, and in parts highly altered; but as these phenomena are intimately connected with the contiguous trap rocks, they will be described in the following chapter. I shall here mention only a few facts connected with the development of the limestone and its organic remains.




52.

At the north-eastern termination of the Nash ridge, some beds of the Wenlock shale with nodules and two thin courses of limestone are thrown off the inferior strata at angles (dipping 50° N.N.E.). The limestone here is fœtid and highly argillaceous. Corals similar to those at Wenlock occur in the way boards of shale, and in the surface of the limestone *Asaphus caudatus, Calymene variolaris, Calymene macrophthalma, Isotelus* (Bar Trilobite), &c., and other characteristic fossils are also met with. This patch of limestone and shale is disconnected from that of the Nash Scar by the protrusion of certain underlying grits of the Caradoc sandstone; but even in the great amorphous masses of limestone in the Scar, *a** of wood-cut, we again find several of the well-known fossils of the formation, such as *Productus lepisma* (Dalman), *Nerita spirata*, and large stems of Crinoidea. Besides these fossils, including Orthoceratites, Mr. Edward Davis[1] has discovered one specimen of the *Pentamerus Knightii* in this limestone, the only exception to the rule which I have laid down, that this fossil is peculiar to the Aymestry limestone. These fossils are, however, found most abundant in the accompanying shale at the north end, and towards the south-western end of the calcareous cliff, where the lines of stratification are best seen, and particularly on the sides of the quarries at Haxwell *a a*, where a bulging mass of the limestone distinctly bedded is thrown off both sides of a nucleus of the quartzose grits of the Caradoc sandstone *b*, as represented in the above wood-cut. The unaltered or slightly altered portions of the limestone are brownish, subcrystalline, and bituminous. They are convertible into lime with a less quantity of coal than the hard crystalline unbedded limestone *a**, called by the workmen "Jew stone[2]." However obscure in the larger

[1] Mr. Edward Davis is son of my friend Dr. Davis of Presteign, to whom I am indebted for much valuable assistance.

[2] The basalt of the Clee Hills is also called Jew stone, p. 126, and the same name is applied to hard quartzose altered coal sandstone near Kinlet, p. 167. This quarriers' term is, therefore, evidently used to designate all hard unmanageable rocks of uneven and splintery fracture, whatever may be their colour and composition.

masses of the rock, planes of stratification may be seen on most parts of the south-eastern face of the cliff above the high road, dipping 60° to the east, and thus they may fairly be said to rise from beneath the Lower Ludlow Shale of the adjoining valley of Knill.

In one of the upper portions of this rock, where the unbedded character prevails, a cavern[1] of about thirty feet by twenty-five was cut into a few years ago. (See letter *o* of preceding wood-cut.)

From Woodfield to Old Radnor the limestone is again lost, but at the latter place it re-appears in great force both on the north-western and south-eastern faces of a hill of trap, sometimes highly altered and dislocated, as will hereafter be described. In other places, however, south of Old Radnor, and at a certain distance from the trap rock, the limestone in its unaltered condition dips gently to the north-west. It is there regularly bedded, grey, and subcrystalline, with way boards of clay, and contains several Wenlock fossils, particularly corals. It passes under the dark-coloured shale of the Vale of Radnor, which represents the Lower Ludlow Rock. Among the many absurd trials for coal in this district, no one appears more inexplicable than the sinking through the shale at this place. The slightest acquaintance with the stratification of rocks would prove, that the shale in which the shaft was sunk rests distinctly upon the limestone. Such trials, therefore, if persevered in, could only establish either the persistence or the thinning out of the limestone beneath this shale. The discovery, however, of the subterranean continuance of this limestone would in itself be valuable, since Old Radnor is the most south-westerly point where any large mass of limestone has been detected in the whole range of the Upper Silurian Rocks of South Wales. It is consequently transported to great distances, even sixty miles; and although there is yet an enormous unwrought mass of it in the Nash Scar and in the low hills south of Old Radnor, it is well to reflect that if the same limestone is regained at a slight depth, which owing to the very gentle inclination of the strata is highly probable, it may be profitably extracted when all the exposed portions shall have been exhausted[2].

## *Lower Silurian Rocks in Radnorshire.*

The Lower Silurian Rocks are little developed near the eastern frontier of this county. Some of their upper beds have been alluded to as forming the nucleus of Nash Hill near Presteign. They there occur in arched, highly inclined, and vertical strata of hard quartzose grits and fine conglomerates, rising from beneath the Wenlock limestone, and throwing off unconformably on the opposite flank, ledges of Old Red Sandstone and Ludlow rocks. Above Corton Gate they contain casts of some of the most characteristic shells of the upper beds of the Caradoc sandstone, such as the *Pentamerus oblongus* and *P. lævis*. There are also traces of these rocks on the sides of the Old Radnor Hills. The greatest mass of them emerges from the surrounding shale in the great trap district of Llandegley, Llandrindod, and Builth, but whether consisting of Caradoc sandstones

[1] I did not examine this cavern, as the many heavy lumps of limestone which had fallen upon the floor would have prevented the possibility of discovering whether it had been the habitation of carnivorous quadrupeds. Like most caverns in limestone its sides and rifts are ornamented with stalactites.

[2] The spot here indicated (the property of the Right Honourable Frankland Lewis) is still nearer to the great non-calcareous region than any of the present works.

or Llandeilo flags, they are so interlaced with trap rocks that they can only be described together in the special account of these rocks which follows in the ensuing chapter.

*Lateral or Western Expansion of the Upper Silurian Rocks in Radnorshire.*

It has been shown that in the west of Salop and the contiguous parts of Montgomeryshire, the whole Silurian system has been repeatedly folded over in undulating masses by the protrusion of trap and the elevation of the Lower Silurian rocks on parallel lines, throwing off in succession the younger deposits. In Radnorshire are only two such lines of disturbance, one extending from Old Radnor to Presteign, along which, as already shown, the Caradoc sandstone is brought to day. The other is that of the Llandegley and Llandrindod district, where trap rocks and strata of similar age reoccur. With these exceptions nearly the whole of the country to the east of the river Ithon is occupied by the Upper Silurian Rocks, which, in the absence of subdividing limestones to limit the Ludlow and Wenlock formations, is simply one great mass of *mudstone* formed of innumerable strata of flag and shale.

In many of the hills, particularly near the summits of those which are not highly inclined, the Upper Ludlow Rock is well marked by its harder character and usual shells, as in the Maen Hill, south-west of the Vale of Radnor, and near the top of Radnor Forest, which is capped by a gritty sandstone (the firestone of that tract) representing the bottom beds of the Old Red Sandstone. The Upper Ludlow Rock, perfectly characterized by its organic remains, is also exposed in variously inclined strata in the gorges of the Teme above Knighton, affording at Felindre a most illustrative passage into the Old Red Sandstone of Clun Forest. (See p. 191, and Plate 33. f. 1.) In nearly all such cases the Upper Ludlow Rock is underlaid by shale, sometimes so hard as to constitute flagstones, and these are succeeded by lower beds of shale of vast thickness, which must therefore occupy the place of the Wenlock shale, for in the Llandrindod country the shelly sandstone and grit appear at once from beneath them. The zone of hard flagstones is precisely of the same age as those which occur in the Lower Ludlow Rock in Radnor Forest, the Black Hill, and many places in Salop. They are very largely quarried, and in slabs of enormous size, at Yechad and at Trevod on the south-eastern slopes of Kerry Hill, and, although not of durable quality when exposed, they are very useful for in-door purposes. They contain *Cardiola interrupta* and *C. fibrosa*, together with *Graptolites*, &c. Similar flagstones of the Lower Ludlow Rock are extracted from the sides of the deep ravines in Radnor Forest with the same and other characteristic fossils, including many Orthoceratites, and in slightly inclined positions underlying the Upper Ludlow Rock. In like manner all the undulating hills south-west of the Vale of Radnor, or between it and the Wye, belong to the Ludlow formation, the lower strata being well exposed in many parts. In the gorges of the Wye, between Erwood and Builth, rocks of this age constitute picturesque grey cliffs, the slightly inclined strata presenting their edges to the eye of the traveller, the rock being in some instances exceedingly hard and compact. In one spot only I observed thin impure calcareous bands, or bastard limestone, viz. near Aber Eddw, about four miles east of Builth, in the hills overhanging the river. As these beds dip under unequivocal Upper Ludlow

Rock, and contain the *Pleurotomaria Corallii*, the *Terebratula Navicula*, *Pentamerus sulcatus*, &c., they probably represent the Aymestry limestone. The heights occupied by these rocks in Radnorshire are marked upon the map, Radnor Forest, the highest, being 2200 feet above the sea. Whilst the strata of these mudstones extending over the north-western highlands of Radnorshire are soft, incoherent, and perfectly useless, with the exception of the very uppermost beds and the lower flagstone, a large portion of the Upper Silurian Rocks on the banks of the Wye are much indurated and very hard, as in the contorted strata in the gorge of Craig-pwll-ddu and in many parts along the banks of the Wye, and also between Erwood and Henault. They are underlaid by very thinly fissile beds, quarried as tiles. It would be useless to specify all the undulations and dislocations of these rocks, in the hills forming the great featureless, argillaceous tracts between Radnor Forest and the Ithon. The new road leading from Builth and Llandrindod to Newtown, ascending by the left bank of the Ithon, is cut through promontories of these rocks, and affords many illustrations of such phenomena, the strata dipping to the E.N.E., E.S.E., and even to the north-west. (Castle Twmpath, Llanbadarn Fynidd, &c.)

In this district, there being no trace of limestone, it is impracticable to subdivide the mass into formations, or even to endeavour to separate with accuracy the Ludlow from the Wenlock formation, the whole representing, as before stated, the Upper Silurian Rocks. They occupy in fact a broad and deep trough, lying between the ridges of the older slaty rocks of the Longmynd on the north-east, and those of similar age on the west, which we are about to describe. By this arrangement the Lower Silurian Rocks never rise to the surface, the upper or mudstone strata being unconformably recumbent along their western frontier upon strata of the Cambrian System. We have before adverted to this phenomenon, which extends along the line of junction of the Silurian and Cambrian Rocks from Montgomeryshire to the borders of Caermarthenshire. (See Pl. 33. f. 1. p. 310, and outline of Map.)

### "*Cambrian Rocks.*"

The right bank of the Ithon exhibits a decided change of mineral character in the mountainous masses called the Foel, the Raltt, Bedugre, and other hills which range from the Valley of the Severn towards Abbey Cwm-hir. (Pl. 33. f. 1.) These mountains are composed of quartzose grits, subordinate to slaty sandstone, probably of the same age as that of the Longmynd or mineral axis of Shropshire, or of Moel-ben-tyrch and other rocks in Montgomeryshire. It is remarkable, that the highest of these mountains, Bryn-dir, the Maen Rocks, and others in the neighbourhood of David's Well (a very slightly sulphureous spring), have all a very determined strike from north to south, by which arrangement they are flanked unconformably by the Upper Silurian Rocks, there being, as has just been stated, no traces in this district of any formations to fill up the interval and to represent those of Caradoc and Llandeilo or the Lower Silurian Rocks. As the ridges of Cambrian rocks approach the valley of the

Clywedog, the stream flowing by Abbey cwm-hir, they veer round to the S.S.W. in the hills of Devanner and Coed trewernan, whence the same strata, sometimes containing thick stony bands, but more frequently masses of schistose and friable structure, resume the true strike of the country, traversing the Camlo Hills from north-east to south-west, and ranging into the prominent ridge of Gwastaden south-east of Rhayader. In the latter district the sandstones assume a decidedly slaty character, occupy a vast breadth, and are traversed from north-west to south-east by the river Wye. The lofty hills of Dol-fan, Rhiw-graid, and Gwastaden are distinguished by summits of coarse slaty sandstone and fine conglomerate. These ridges are parallel, ranging from north-east to south-west, and the strata, though sometimes dipping to the south-east, are for the most part thrown over, at greater or less angles, to the north-west. (Pl. 33. f. 7.) In the Gwastaden Hills the quartzose slaty sandstones and conglomerates dip from 35° to 50° to the north-west. They pass into coarse roofing slates, which occur in the hills both south-east and north-west of Rhayader, and at the fall of the Wye. Some of the finest examples of these slaty rocks [1] and their associated conglomerates are in the deep gorges of the river Elain, a tributary of the Wye, particularly in the crags called Cefn Craig-y-foel, where very large, apparently concretionary masses of coarse conglomerate, are interstratified with slates, the whole much twisted and contorted, dipping to the north-west. Thin veins of lead occur, and have been worked near the sources and on the banks of the river Elain.

These Upper Cambrian Rocks graduate into the older slaty rocks of Wales. There is, indeed, no well-defined line of separation between the coarse quartzose slates of Rhayader and the masses of more crystalline slate which are repeated upon parallel lines between that town and Plinlymmon (Plyn-lumon of the Ordnance Map). They all belong to the upper group of the Cambrian System, and are of the same age as many mountains in Montgomeryshire (Moel-ben-tyrch, &c.), the whole of which have been proved by Professor Sedgwick to be of younger date than the slates of Merionethshire, &c.

### *Trap and altered Rocks in Radnorshire.*

Between the south-western termination of the various ridges of trap of Shropshire and Montgomeryshire, and the rocks of the same character in Radnorshire, is a space of eighteen or twenty square miles entirely void of volcanic matter, being exclusively occupied by undulating strata. Round-backed hills of Upper Silurian Rocks occasionally carry over upon their surface the lowest beds of the Old Red Sandstone. The Radnorshire trap rocks diversify these soft hills, by shooting up in distinct stony ridges, running from north-east to south-west. The most eastern is the Old Radnor

[1] By consulting the section, Pl. 33. f. 7, it will be seen that these slaty rocks contain within them vast masses of incoherent shale and hard grit.

group; the central or chief mass is included between Llandrindod and Llandegley on the north-east, and Builth on the south-west, whilst a third and very short ridge, precisely parallel to the others, occurs at Baxter's Bank, five miles north-west of Llandrindod.

### *"Old Radnor Group."*

The trap of these hills bursts out through the formations of the "Silurian System," throwing off the Ludlow Rocks of Bradnor Hill and Hergest Ridge to the south-east, and breaking up the inferior shales and the Wenlock limestone in the vicinity of Old Radnor. It occupies two distinct parallel ridges, separated by a valley of shale and limestone. The eastern, about three miles in length, comprises the Stanner Rocks, Worsel Wood, and Hanter Hill, which are severally 1000, 900, and 1200 feet above the sea; the western, called Old Radnor Hill, is 1100 feet in height, and only half the length of the other[1]. The vale inclosed between these ridges communicates with the low country, upon the east, by a transverse depression, which separates Stanner Rocks from Worsel Wood and the hill of Bradnor from that of Hergest, both composed of the Ludlow formation. (See Pl. 33. f. 3.)

### *Stanner Rocks.*

The north-eastern extremity of the trap of this hill ranges into low hummocks between the farm of Old Harpton and the south-western flank of Herrock Hill, whence it is traceable into the narrow ridge of Stanner Rocks, forming the foreground of the sketch prefixed to this chapter, which, rising to the height of 1000 feet, terminate opposite Worsel Wood in a precipitous cliff. The trap of this and the adjoining hills resemble the hypersthene rock of Coruisk in the Isle of Skye, described by Dr. MacCulloch[2]. Like the rocks of Coruisk (which I have examined *in situ*) these of Old Radnor pass from a coarse crystalline hypersthene rock into fine-grained greenstone, in which the separate crystals of hypersthene are no longer perceptible. The base, however, is for the most part dissimilar from that of Skye in the white and sometimes pink colour of the felspar, and in containing also mottled and slaty varieties of compact felspar, some of which are of a bluish colour, glossy surface, and brittle fracture. The felspar rocks are also granular, and in some few instances porphyritic. In the vertical cliff, in addition to numerous varieties of hypersthene, felspar rock and greenstone, is a very hard compact stone of a black colour and polished surface, probably an intimate

[1] The sketch facing the first page of this chapter represents the eastern ridge; Stanner Rocks in the foreground, with Worsel Wood and Hanter Hill beyond. The high ground in the distance is Hergest Ridge, composed of the Ludlow formation.

[2] On referring a fragment of this rock to Professor Miller of Cambridge he has favoured me with the following account of it:—"The dark mineral has one very perfect cleavage, and a dull face or imperfect cleavage nearly at right angles to the former. Alone, on platina wire, it is fusible with difficulty. It dissolves slowly but completely in borax, giving a head coloured by iron. The powder of the mineral is not sensibly acted upon by hot sulphuric acid. It scratches fluor. The mineral is probably the variety of augite (hornblende), called diallage, brongite, or hypersthene."

admixture of felspar and hypersthene, which contains veins of white calcareous spar and crystals of iron pyrites. On one of the gnarled summits of these rocks are patches of a quartzose conglomerate, of which more will be explained in describing Old Radnor Hill.

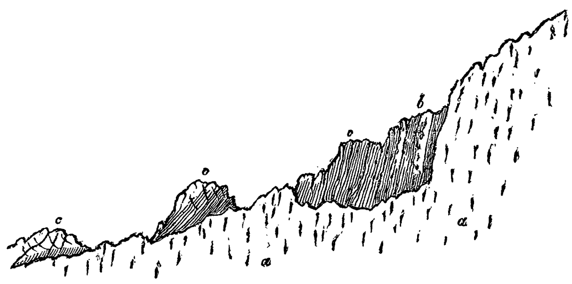
*Worsel Wood.*—This is the small central conical hill seen in the sketch prefixed to this chapter. It is covered with trees and offers little of interest on the surface, but near its base I found dark fine-grained compact felspar, and traces of the same varieties of trap as in Stanner, with much disseminated calcareous matter.

*Hanter Hill.*—In this hill, the most prominent of the group, are many of the modifications of hypersthene rock described in Stanner; the coarse-grained whitish and greenish felspar, traversed by crystals of dark-coloured hypersthene being predominant. Some masses of this bold and conical hill are of a slightly porphyritic structure; others consist of slaty and concretionary felspar rock, with crystals of common felspar.

The coarser varieties of the hypersthene rock apparently occur near the summit, and in some of them carbonate of lime is disseminated between the crystals of hypersthene and felspar. Iron pyrites is common.

*Old Radnor Hill.*—The mass of this hill is a dark greenstone or hypersthene rock, and with a somewhat concretionary trap, which has a fragmentary aspect, owing to small cracks traversing the rock. Masses of grey and pink compact felspar, passing into impure serpentine, are quarried near the church. These and modifications of greenstone are also found in the knolls around the Brookkiln limestone quarries, &c. Nests and thin coatings of anthracite accompany the trap of Old Radnor, as also crystals of copper and iron pyrites.

53.




*a.* Trap (Old Radnor Hill). *b.* Conglomerate. *c.* Limestone.

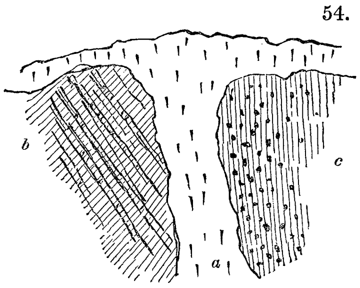
Thrown off the western flanks of Old Radnor Hill (*a* of this wood-cut) is a peculiar conglomerate (*b*). It has a base of grey and green compact felspar, inclosing pebbles of quartz of the size from a bean to that of a man's fist, and occasionally grains of quartz. From this composition it may be inferred that a stream of compact felspar, or submarine lava, entangled in it the sand and pebbles of a former bed of the sea. This conglomerate appears in various little bosses, and is well seen on the sides of an old lane which ascends from Harpton Court to Stockwell. (Pimply rock of Stockwell Scar.)

On the actual side of the hill, and 200 to 300 feet below its summit, is a mass about forty to fifty feet in width of the conglomerate grit, in almost vertical strata, having all the appearance of greywacke grit. This passes beneath the limestone (*c*). It is certainly a stratified deposit, occupying the same place in the series as the volcanic grits of the Caradoc which underlie the Wenlock limestone, and like them the pebbles and sand have been accumulated in the same manner with the detritus of submarine volcanoes during the formation of the Silurian strata, the bedded masses being afterwards thrown up by subsequent eruptions to their present positions.

*Effects produced by the trap eruption of Old Radnor upon the contiguous limestone.*

The ordinary phenomena of sedimentary deposits, being altered and dislocated in contact with trap, are displayed at numerous points around the hill of Old Radnor; here the conglomerate is raised into vertical walls between the trap and the limestone, there the shale is converted into an indurated slate or Lydian stone. But besides these relations, the trap is seen in several places to penetrate the limestone. This phenomenon is well shown at various places near the south-western termination of the hill of Old Radnor, on both sides of the road leading to Gladestry, under the Ivy Scar, at the Brook lime-kilns, &c. At the lime-works of Yat Hill, which are a few hundred paces distant from the trap, the limestone dips at a slight angle from the hill and is regularly bedded, but as it approaches the trap it becomes shattered, dislocated, and finally quite *un*stratified. Most of the calcareous masses which have been quarried out at different levels from the abrupt face of the trap are fœtid, and the two or three feet nearest to that rock are usually in a highly brecciated and altered state. A little west of the Ivy Scar, the limestone having been peeled off the face of the trap rock, the thin coating abandoned by the workmen is in a brecciated state, resembling old mortar, with an occasional seam of serpentine between the crystalline limestone and the trap.

54.




Here the trap forms a dyke about sixteen feet in width (*a*), having the frothy breccia (*c*) on one side, and bending over on the other upon an irregularly bedded mass of limestone (*b*), the strata of which dip very sharply to the north-east. In this case the trap (compact felspar and decomposing greenstone) appears to have risen through, broken up, and overflowed the limestone, twisting back its elevated strata in the manner here represented.

The serpentine which forms the back of the Brook lime quarries is from twenty to thirty feet wide, the limestone in contact is very hard, completely unstratified, and highly fœtid under the hammer.

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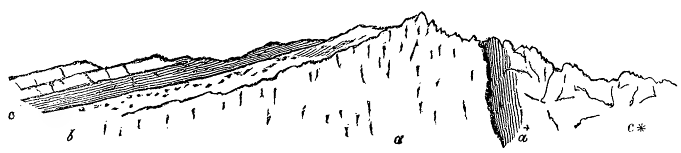



*a*. Trap. *b*. Conglomerate. *c*. Unaltered limestone and shale. *a**. Serpentine. *c**. Altered limestone.

In this locality the trap throws off to the west or opposite side of the quarry some beds of the quartzose conglomerate (*b*), which by its dip passes under the regularly bedded adjacent limestone (*c*). One of the pebbles from these beds appeared to have undergone fusion, and induced me to think that some of this conglomerate might be of concretionary origin. On the other side of the trap (*a*) the relations are very different, the intrusive rock being separated from the limestone by a thin band of serpentine (*a**), while the limestone itself (*c**) is no longer stratified, but a hard, crystalline, amorphous mass which has been deeply excavated. Where the serpentine folds over this rock, its surface is polished.

In every instance where similar phenomena have been laid bare around Old Radnor, the bands of serpentine between the intrusive and the bedded rocks are more or less penetrated by veins of calcareous spar, of which mineral there are no traces in the heart of the trap rock, which is then either pure compact felspar, hypersthene, or greenstone.

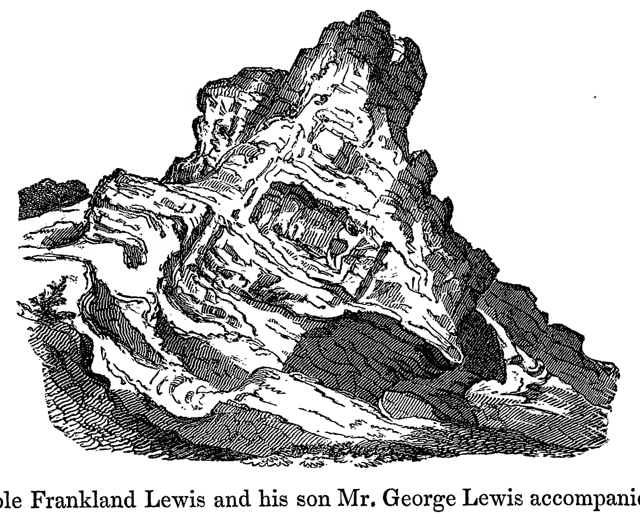
Nests and thin coatings of anthracite are also of frequent occurrence on the exterior of the trap, and are occasionally found some distance within the altered bedded rocks, associated with minute veins of copper ore and crystals of copper and iron pyrites.

At other points of contact where the trap throws off the shale, the latter is in a highly indurated state, almost Lydian stone, and breaks into numerous small fragments[1].

The phenomena of the altered deposits in contact with the trappean hills of Old Radnor are in many respects analogous to those observed in other parts of this region, with the difference, that the actual insertion of the trap into the limestone, and the consequent alteration of the latter, are more plainly exhibited than in Shropshire. Comparing small things with great, I may say, that the changes at Old Radnor are precisely analogous to those of the Val di Fassa in the Tyrol, where numerous dykes and protruding masses of trap, carry up on their flanks dislocated portions of shale and limestone, the latter being frequently changed into a marble, usually separated from the intrusive rock by a similar coating of serpentine. In the alterations of the Silurian formations, we have every proof that the intrusive volcanic rocks penetrated the limestone posterior to its consolidation. Not only are the traces of bedding obliterated as the strata approach the trap, but the whole texture of the rock is changed; being converted from an ordinary, earthy, sub-crystalline limestone into a mottled, veined, and hard marble. Shells and way-boards of division, so common in the strata a few paces from the trap, disappear in these amorphous masses of limestone, which exhibit, on the contrary, veins and nests of anthracite, copper ore, &c.

The effects of the subterranean agents which produced these changes at Old Radnor are not confined merely to the flanks of that hill. We find that the line of this axis of elevation has been prolonged to the north-east through the Nash Scar to Corton turnpike-gate, in which space the same causes must doubtless have operated; for although no trap is visible, the magnificent mass of highly crystalline and altered limestone, a part of which is represented in this wood-cut,

56.



[1] The Right Honourable Frankland Lewis and his son Mr. George Lewis accompanied me in an examination of these rocks, and were of essential use in directing my attention to points of interest.

and the contorted strata which occur on the sides of this altered mass, sufficiently well explain what we have described in the south-western prolongation of the same axis at Old Radnor.

There is not, perhaps, in Great Britain a finer mass of altered and crystalline limestone than that exhibited at Nash Scar, the principal cliff of which rises to the height of 200 or 300 feet above the adjoining valley of Knill and Presteign. At Woodside and Haxwell, to the south-west of the Scar, the limestone is stratified, as represented in the wood-cut, p. 313, and at the latter place apparently folds around a nucleus; but in receding from this point to the north, the stratified characters disappear and it rises in large and contorted folds towards the chief mass, where all traces of bedding vanish.

Again, at the north-eastern extremity of this ridge, near the spot marked Folly on the Ordnance map, are thin bands of limestone, subordinate to shale, which dip at a high angle, overlying the grits as at Old Radnor. As these beds recede from the scene of disturbance they become *un*altered, the shale being abundantly charged with *Asaphus caudatus*, *Calymene variolaris*, and *C. macrophthalma*, the *Isotelus* (or Bar Trilobite), &c. They mark, indeed, by their position and by their wrapping round the north-eastern end of the ridge, the extreme point of prolongation of the axis of the Old Radnor elevation.

Although no intrusive trap has yet been discovered beneath or on the sides of the Nash limestone, the Corton conglomerate, which has been largely cut into near the north-eastern end of the ridge, and protrudes from beneath the limestone, strongly resembles a volcanic grit. It is excavated to the depth of forty feet, and appeared to me to be *un*stratified towards the bottom. The stone has been largely quarried for rough masonry, and the new jail at Presteign is built of it. The matrix is a greyish blue felspar, enveloping fragments of greywacke and quartz. (See p. 320.)

As the line of broken and altered limestone of Nash and Old Radnor marks the last tract towards the south-west, where any calcareous mass worthy of being worked, is found in the Silurian rocks of South Wales, the demand for the limestone is so great (being transported fifty and sixty miles into the slaty and quartzose districts,) that so much of this great boss of Nash Scar may be consumed as will enable future geologists to discover the intrusive rocks, which I doubt not exist beneath this converted limestone. This inference is deduced from the evidences of eruption and the changes produced in the prolongation of this same line of fissure at Old Radnor, distant only three miles.

The strata of the Silurian System which are thrown off to the south-east and north-west of the trappean axis of Old Radnor, are the Ludlow and Wenlock formations and a small portion of the Caradoc sandstone. We further know that this eruption must have taken place subsequent to the deposit of the Old Red Sandstone, as stripes and patches of the lower part of that system are observed upon either side of the axis of elevation in highly inclined and dislocated strata, both in the Radnor woods west of the Nash Scar, and again at Llantowel between Old Radnor and Gladestry. (See p. 192.)

By reference to the map, it will be seen that the volcanic outburst we have just described, is a key which satisfactorily explains the elevation of other tracts where no trap appears at the surface; for the line of fissure if prolonged, is precisely coincident with the axis of elevation of the Ludlow promontory and with the great Brecon anticlinal, to be described in the twenty-seventh chapter.

We may conclude our notice of this tract by stating that, though upon a less scale

than the phenomena of the Val di Fassa, these of Old Radnor serve to explain more clearly how shelly stratified deposits have been elevated, dislocated, and altered by the intrusion of volcanic matter. Yet this interesting spot, which is also so attractive to every lover of fine scenery from the varied and picturesque outline dependent upon geological structure, and exhibiting in the composition of its trap rocks the mineral called hypersthene, formerly supposed to be peculiar to one district only of Great Britain, has never elicited any scientific description, although within one hundred and fifty miles of the metropolis[1].

[1] It appears from recent observations of M. de la Beche that hypersthene rock exists also in Devonshire.

# CHAPTER XXVI.

## TRAP AND ALTERED ROCKS OF RADNORSHIRE (*continued.*)

*Group of Llandegley, Llandrindod, and Carneddau near Builth. Mineral Waters of these Tracts.*—(Pl. 33, figs. 3, 4, 5, 6 & 7. See also Map and opposite sketch of the southern end of Carneddau, near Builth.)

THE largest trap district of Radnorshire extends from Llandegley and Llanbadarn-fawr on the north-east and north, to the environs of Builth on the south-west. Its extreme length from Llandegley Wells to the Park Wells near Builth is nearly ten miles, and the greatest breadth from Blaen Eddw and Bettws Disserth to Cefn Lys and Llandrindod Common, is upwards of five miles. From Llandegley to Builth, the main ridges of trap are the Llandegley rocks, Sunny-bank, Gelli, and the Carneddau. Besides these, a great embranchment is thrown out on the north-west by Carreg-gwiber and Cwm-brith Hill to Cefn Llys, and the hillocks north of Llandrindod Wells. On the eastern or south-eastern flank of the main ridge, and running parallel to it, are a number of smaller, elongated mounds of trap, having the same direction, from Blaen-Eddw and Llandegley Rhos on the north-east, to Llansaintfraed and Llwyn-Madock on the south-west. Many of these trap ridges inclose longitudinal valleys, excavated in the lower Silurian shale and flag, the beds being tilted in divergent directions upon the opposite sides of the intrusive rocks, and changes in the mineral character of the deposits are usually visible at the points of contact. The same phænomenon is also seen at some places on the north-western face of the chain, between the Gelli and the banks of the Ithon near Llandrindod; the most instructive example being perhaps that between Gwern-y-fad and Builth, on the banks of the Wye. In addition to these intrusive rocks, amid some of which the strata are thrown into lofty hills, are distinctly *stratified* traps, alternating with beds of marine sediment.

This district, therefore, is precisely similar in its relations to the tract of Shelve and Corndon, previously described; and it is made up of similar ridges, and deeply trenched narrow valleys, running from north-east to south-west[1]. Great portions of the surface are arid and barren, particularly the sloping banks, moors and commons near Llandegley and Llandrindod. This sterility is perhaps greatest, where the soil consists en-

[1] This tract is as impassable and little visited as that of Corndon and Shelve, Shropshire.

tirely of light yellow clay, the decomposed felspar so predominant in the central ridges; and particularly when the surface is choked up (as near Llansaintfread), with numerous loose quartzose boulders, transported from the west. I will first describe those trap rocks which are distinctly interstratified with the fossiliferous deposits, the general relations of which are fully explained in the coloured section, Pl. 33. fig. 5. They prevail in the northern portion of the district, and their centre may be placed in the hills of Gelli and Gilwern, whence they are prolonged to the south-west by Upper-house, Beili-brith, Carreg-gwiber and Bryn-hir (near the Three Wells); and to the north-east in the hills of Llandegley and Cefn-Llys. In the Gelli and Gilwern hills, these bedded trap rocks attain the greatest heights, and consist of the following varieties.

1. Dark grey compact felspar, slightly porphyritic, having a few imbedded crystals of common felspar. It contains, also, dark green flattened concretions, which mark the laminæ of deposit, their edges passing into a kind of steatite or serpentine.

2. The same rock, with concretions of quartz and felspar, having an agate-like arrangement, the whole streaked by irregular films of serpentine, giving it a laminated, green and white aspect.

3. Grey granular trap, made up of felspar, quartz, and iron pyrites, with a little of carbonate of lime disseminated; the felspar occasionally collected in very small concretions.

4. Clay-stone of blue milk, and light grey colours, with a few crystals of common felspar, fracture more or less conchoidal, surface dull, with spots or minute concretions, sometimes hollow, and containing earthy matter with pyrites.

5. Same rock as 4, but more earthy, and of greenish-grey colour.

6. Do. do. more slaty, has at first sight the aspect of compact felspar porphyry, but when magnified, proves to be a dull, granular claystone, with some concretions of felspar and many crystals of pyrites.

7. Felspar porphyry, approaching in parts to the clinkstone of Werner, of a dark greenish-grey colour, weathering outside to a rusty-brown: the decomposing felspar crystals leave small cavities.

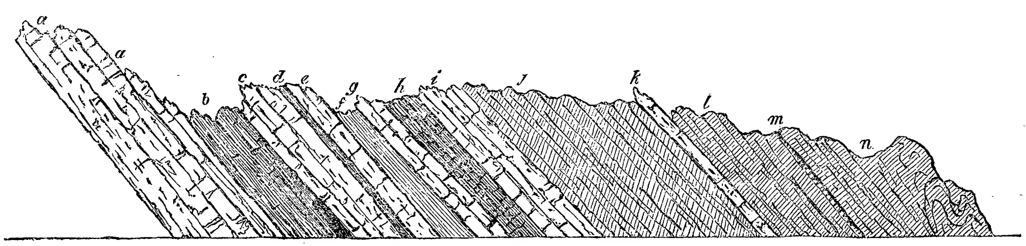
Carbonate of lime occurs in small veins in these laminated traps, occasionally slightly intermixed with the other minerals.

In the Carreg-gwiber quarries, one of the light-grey felspar rocks, having its lamination marked by dark, rusty-brown, elongated blotches of decomposed green earth, is much extracted as a building stone. In the Berrw and other places, a cream-coloured and delicate green, fine granular felspar rock is used as an oven or fire-stone.

The prevailing inclination of these *bedded traps* is to the north-west, as may be seen by crossing the main ridge from the valley of the Eddw to Llandrindod, and the prevailing angle of dip is 40° to 45°; thick and thin beds alternating with the flags. On descending from the north-western face of Gelli, a brook, the chief feeder of the Howddy, rushes down a narrow chasm, the Cwm-re, in which this alternation is admirably displayed; and as the flags contain the *Asaphus Buchii*, it is manifest that submarine volcanic operations were in activity during the deposition of the sand, mud and crustaceans which formed the Llandeilo flags.

The bed of this brook on the side of the hill presents the following very instructive section. (Pl. 33. fig. 5., and this wood-cut.)

57.



| | | feet. | inch. |
|---|---|---|---|
| *a.* | Coarse slaty felspar rock, slightly porphyritic and amygdaloidal, containing elongated concretions of green earth. It is regularly stratified in beds of 3 to 4 feet thick, and forms the mass of the hill, rising into the higher ground. | | |
| *b.* | Finely laminated greenish-grey sandy flagstone, apparently hardened near the trap | 50 | |
| *c.* | Fine-grained granular felspar and courses of clay-stone, some of which are used as oven stone | 30 | |
| *d.* | Altered flags, having a conchoidal fracture, in parts almost Lydian-stone, with crystals of iron pyrites | 10 | |
| *e.* | Grey felspar rock, the laminæ of deposit marked by ferruginous streaks probably due to the decomposition of some other mineral. A thin transverse vein of quartz with some lead (ranging south-easterly) induced some of the inhabitants to drive a gallery across the beds, an effort which terminated as fruitlessly as all the other mining speculations in these hills | 15 | |
| *f.* | Black shivery shale, containing a few concretions of argillaceous limestone, with veins of calc spar. One of these which fell under my notice was a septarium, two to three feet in diameter, containing many impressions of *Graptolites*[1] | 10 | |

(This band of black shale has been recently excavated to a considerable distance on the strike of the beds by the same individuals who have sought for lead ore. In this case their object was coal, necessarily a great desideratum in a district so far removed from any coal-measures. The ignorance of the speculators in this case was surely never parallelled, their gallery having been driven for the whole distance in *the very same stratum* of shale, with an inclined wall of trap rock upon each side of it.)

| | | feet. | inch. |
|---|---|---|---|
| *g.* | Hard, thick-bedded porphyritic felspar | 4 | |
| *h.* | Flagstone with *Asaphus Buchii*; indurated in contact with the trap; much iron pyrites | 20 | |
| *i.* | Grey porphyritic clay-stone | 25 | |
| *j.* | Black schist, with some hard stone bands, in parts pyritous | 100 | |
| *k.* | Slaty porphyritic felspar | 5 | |
| *l.* | Black shale, with stone bands and concretions of argillaceous limestone | 30 | |
| *m.* | Thin band of decomposed, granular felspar, weathering to a rusty colour and looking like a coarse oolite | | 3 |
| *n.* | Black pyritous schists, much contorted near the mouth of the gallery | 40 | |
| | Total | 353 | 3 |

Thus in 350 feet are exposed twelve bands of stratified trap, alternating with Silurian schists and flagstones.

The black shale decomposing into thin shivery fragments, has frequently induced the belief that it was coal shale, and it has in consequence been repeatedly explored for coal. The same individuals who foolishly excavated so far in the same black stratum in search of lead ore, had previously driven a gallery to find coal 40 yards across these very inclined strata, the edges of which are exposed on the sides of the adjoining gulley. Thus they actually drove through those very beds of which the rivulet had already explained the true nature. It is needless to add, that when the work reached one of the hard bands of trap, above-mentioned, it was abandoned. I shall presently advert to other coal adventurers in this district, p. 328.

Similar alternations of flagstone, containing the *Asaphus Buchii*, with layers of slaty felspar rock inclosing much green earth, are found at Upper Gilwern on the elevated southern slopes of the Gelli, where both these varieties have been long quarried as tile-stones, the coarser or refuse beds serving as wall-stones. In the bold promontories which run out from these central masses to the north-east towards Llandegley, particularly on their north-western slopes, are many alternations of stratified trap and sandstone charged with casts of Caradoc shells. (See Pl. 33. fig. 6.) A section from the north-western foot of these ridges exhibits

1st. Overlying dark shale, with slightly calcareous nodules dipping 20° N.N.W. (base of the Upper Silurian Rocks.)

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[1] This species of Graptolite differs from the *G. Ludensis* of the Lower Ludlow Rock. (See p. 206. and Pl. 26.)

2nd. Several alternations of porphyritic, bedded felspar, with shelly, brown, Caradoc Sandstones, dipping conformable with the above, the angle increasing with the rise of the hill. The sandstone is worn into depressions, and the trap forms ridges[1]. The former contains the shells.

3rd. The whole of the hill called Llandegley rocks consists of bedded trap, the direction of the beds being perfectly conformable to those which alternate with shelly sandstone on the exterior slopes; but the angle of inclination having increased in each successive ridge, amounts to 60° and 70°, dip N.N.W. These are the rocks which present rugged escarpments to the south-east, where they are largely quarried as Llandegley *building* stones. In the depression north-east of this escarpment, and also in descending to the village of Llandegley, are several bosses of *un*stratified trap, which seem to rise irregularly through the surrounding deposits, and throw them off on all sides, producing veins of quartz, coats of anthracite, cavities filled with green earth, &c., in the surrounding strata. These are felspar rocks, sometimes porphyritic, passing into greenstone and quarried for the roads.

The Llandegley rocks offer a fine bold front to the north-east and constitute the termination of this trap district. They send out a small dyke or spur of porphyritic greenstone, which traverses the black shale with nodules in the bed of the brook close to the sulphureous wells. The inferences deducible from this fact will be rendered more apparent when we have examined the relations of the rocks in the vicinity of the other sources of mineral water which surround this tract, p. 334. At Blaen Eddw, near the source of the sulphureous spring, is the same juxta-position of unconformable trap and shale. The same at Llandrindod and at the Park Wells near Builth.

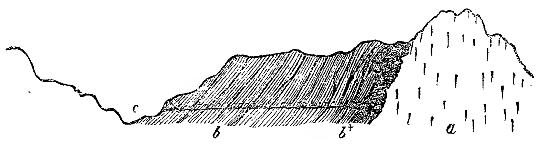
In the vicinity of Blaen Eddw are several small protuberances of highly crystalline, coarse-grained greenstone, with a little lime disseminated, and also white and grey, granular felspar rocks, which tilt the strata to the north-west and south-east, the latter being usually much hardened at the contact with the trap. These bosses are not continuous for any great length; but they are succeeded on the west by another parallel ridge of similar composition, which terminates in the fine bold rock of Craig-fawr, the direction of which may be followed in the stony hill of Coed-mawr. The prevailing rock in these ridges is greenstone and porphyritic greenstone, highly crystalline, and generally with a little lime both disseminated and in veins[2]. Other bosses, all protruding in parallel lines which range from north-east to south-west, are found near Bettws Disserth and Tin-y-coed, extending from the south end of the Llandegley rhos to the rocks south-west of Llansantfread. Another and a shorter parallel is seen in the neighbourhood of Llwyn madoc. In all these cases the central bosses of trap have been thrown up in irregular masses without any appearance of bedding, but towards their flanks is frequently a passage into distinct, slaty and bedded rocks, still preserving a trappean character. This is well seen near Coed-mawr, where there is a transition from a coarse greenstone in the centre of a small hill to a slaty exterior of altered flags (in part a complete flinty slate if not a Lydian stone) with many crystals of iron pyrites. Receding from the trap the alteration disappears, and in the valley of Bettws, near the little chapel, is the ordinary thinly foliated black shale of the country. The black colour in this instance has again misled the

[1] A beautiful variety of grey volcanic grit has been recently quarried at the Graig for the construction of the bridge at Pen-a-bont, the strata dipping west 35°.

[2] Several large blocks of these trap rocks, having a rude columnar form, are arranged in a circle on the dreary common of Rhos maen, about one mile east of Craig-fawr. They resemble the Druidical circles of the Isle of Arran and others which I have met with in geological rambles. I am not aware that this Druidical circle has been described by any antiquary. Its place is marked in the Map.

inhabitants of this dingle, and galleries have been driven horizontally through these inclined beds in search of coal. A transverse section from this spot to the chief focus of eruption around the Gelli exhibits at least two other distinct small ridges of trap (porphyritic greenstone and felspar rocks) alternating with shale. At Tin-y-coed, I found a credulous farmer ruining himself in excavating a horizontal gallery in search of coal, an ignorant collier being his engineer. This case may serve as a striking example of this *coal-boring* mania in districts which cannot by possibility contain that mineral, and a few words concerning it may, therefore, prove a salutary warning to those who speculate for coal in the Silurian Rocks.

Tin-y-coed. 58.




*a*. Trap. *b*. Black schist. *b**. Schist altered in contact with trap. *c*. The gallery.

The farm-house of Tin-y-coed is situated on the sloping sides of a hill of trap (*a*), which throws off, upon its north-western flank, thin beds of black greywacke shale (*b*), dipping to the W.N.W. at a high angle. The colour of this shale and of the water which flowed down its sides, the pyritous (sulphureous) veins and other vulgar symptoms of coal-bearing strata, had long convinced the farmer that he possessed a large hidden mass of coal, and unfortunately a small fragment of real anthracite was discovered which burnt like the best coal. Miners were sent for, and operations commenced. To sink a shaft was impracticable, both from the want of means and the large volume of water. A slightly inclined gallery (*c*) was therefore commenced, the mouth of which was opened at the bottom of the hill on the side of the little brook which waters the dell. I have already stated that in many cases where the intrusive trap throws off shale, the latter preserves its natural and unaltered condition to within a certain distance of the trap; and so it was at Tin-y-coed, for the level proceeded for 155 feet with little or no obstacle. Mounds of soft black shale (*b*) attested the rapid progress of the adventurers, when suddenly they came to a "change of metal." They were now approaching the nucleus of the little ridge, and the rock they encountered was, as the man informed me, "*as hard as iron*," viz., of lydianized schist (*b** of wood-cut), precisely analogous to that which is exposed naturally in ravines, where all the phenomena are laid bare. The deluded people, however, endeavoured to penetrate this hardened mass, but the vast expense of blasting it put a stop to the undertaking, not, however, without a thorough conviction on the part of the farmer that, could he but have got through that hard stuff, he would most surely have been well recompensed, for it was just thereabouts that they began to find "*small veins of coal*"!

It has before been shown that portions of anthracite are not unfrequent in the altered shale where it is in contact with intrusive rock. And the occurrence of the smallest portion of anthracite is always sufficient to lead the Radnorshire farmer to suppose that he is very near "El Dorado [1]."

The western side of this longitudinal valley of Tin-y-coed or Cwm mawr is bounded by loftier hills, on the flanks of which is much altered and contorted rock; with some points of eruptive trap. In the central district of Gelli, are many appearances of conformable alternation of shale with trap and porphyritic flags. The north-western branch of this region ranges to the prominent rock of

[1] Amid all their failures I never met with an individual who was really disheartened; a frequent exclamation being—"Ah! if our squires were only men of *spirit* we should have as fine coal as any in the world."

Cefn Llys and to numerous knolls around and north of the church of Llandrindod, the best of which is seen at Cet tws, about one mile south-east of Llanbadarn-fawr. The rock is here a light grey greenstone, containing much carbonate of lime, in strings and in larger veins, evidently of contemporaneous origin. This rock is also penetrated by dark ferruginous, pyritous veins. To describe all these knolls would be useless repetition, the phenomena being invariably the same as those detailed on the eastern side of the main ridge. At Llanfawr, north of the Pump House, the rock is well exhibited, being largely cut into for the use of the roads. It is here a highly crystalline greenstone, composed of hornblende and grey felspar more or less crystallized. The same rock appears also near the Wells. In the hillocks around Llandrindod church are amygdaloids with kernels of quartz sometimes coated with anthracite. These and other varieties protrude in almost countless bosses, the schist or flagstone between them being highly indurated, dislocated, and always much contorted. The mineral water of Llandrindod issues from black shale near one of these points of contact. (See the end of the Chapter.) To the west of the springs the dull features of Llandrindod Common, Llanyre Rhos, and the banks of the Ithon, are relieved by the rapidly undulating outline, due to the mixed nature of the rocks, the soft shales being excavated into deep and narrow ravines between these protuberances of trap. Among the latter there is no one more picturesque than the rock on which stood the ancient fortress of Cefn Llys. Here the river Ithon, in its course from the north-west, suddenly deflects and follows the edge of the main ridge of the trap hills in a sinuous channel excavated in the Lower Silurian Rocks, winding round Cefn Llys, which is thus almost peninsulated. Cefn Llys is composed of a coarse felspar rock, having a tendency to porphyritic structure, and on one hand passes into a fine granular rock, on the other to compact hornstone, sometimes very thin-bedded and slaty. On the summit are the remains of buildings and foundations, &c.[1]; but towards the northern end of the hill the trap assumes the bedded character so frequently observable in other parts of this district. The well-wooded and deep valley near the little church is singularly beautiful; where the Ithon emerging from this volcanized region through a narrow gorge of trap rocks, passes between cliffs of about forty feet in height, from the sides of which a single plank serves as a bridge over the stream[2].

The covered nature of most of the depressions in this disturbed tract renders it exceedingly difficult, if not impossible, to mark the nature of all the rocks beneath the surface. These valleys are for the most part loaded with thick accumulations of the detritus of the adjoining ridges of trap and altered deposits, the harder varieties of which form large angular boulders associated with much cold, light yellow clay, the residue of the decomposed felspar. On the flanks of this district it is not, however, difficult to mark with precision that the valleys really consist of a subsoil of black shale, schist and sandstone, forming the Lower Silurian Rocks, i. e., from the base of the Wenlock formation to below the Llandeilo flags, including the Caradoc sandstone. The manner in which some of these deposits are affected by the intrusive ridges of trap has already been pointed out.

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[1] Cefn Llys is one of the Radnorshire boroughs.

[2] This repeated alternation of trap and stratified deposits renders it impracticable to lay down every such occurrence except upon a map of very large scale.

### *Baxter's Bank.*

Another small ridge of trap rock, in the neighbourhood of Llandrindod, called Baxter's Bank, remains to be noticed [1]. It is situated about five miles north-west of Llandrindod, about three quarters of a mile south-east of Camllo Hill, and two miles and a half from the sequestered valley of Abbey Cwm-hir. The adjacent country consists of round and featureless hills composed of black decomposing shale, with concretionary masses and ribs of quartzose conglomerate; the latter, however, occur only to the west and north-west, and are part of the upper division of the Cambrian System before described at Gwastaden and Rhayader. The hill called Baxter's Bank is a narrow wall of trap, 500 feet high and rather more than half a mile in length. Its course is from north-east to south-west, and therefore parallel to the ridges of Llandrindod. The rock is partly a coarse-grained hornblendic greenstone, passing into a fine-grained and more felspathic variety, partly grey-coloured granular felspar with dark freckles, probably hornblende. The flanks of this wall of trap present precisely similar altered and dislocated strata to those mentioned in other places. Near the Carmel chapel, the beds thrown off are thick and hard white veined blue flags, quarried as building-stones, some of them perhaps deserving the name of volcanic grit. On the north-west flank near Rhiw-goch, the black shale unfortunately appearing carbonaceous, has again induced individuals to drive horizontal galleries in search of coal through the highly inclined strata until stopped by the highly indurated and silicified schist which here, as in other districts, is connected with igneous rocks. In this case the mistake of the speculators is, if any thing, still more inexcusable than in the instances previously cited, for this little ridge is traversed by a road at its north-eastern termination, where the unaltered and the indurated shale near the trap have been long clearly exposed, and an inspection of the section on the side of the road might have saved the miners the trouble and expense of underground drifts. About one mile south-south-west of Baxter's Bank, another little boss of trap is quarried on the north side of the high road from Radnor to Rhayader, near a spot called Caer-fagü. Here the intrusive rock tilts the black schist to the north-west, which in contact is hardened and silicified. The trap of Caer-fagü is a spotted, granular felspar rock with a tendency to amygdaloidal structure, and is much discoloured on the exterior by ferruginous stains: it is traversed by veins of quartz, the whole being in a state of decomposition. It is covered by an accumulation of sandy detritus, including pebbles derived from the rocks of the adjoining district.

### *Carneddau and Builth.*

In the southern and south-western extremity of this district are the loftiest and most important masses of intrusive trap rocks. It will now be shown that as many of the stratified trap rocks of the Llandegley district were evolved from volcanic apertures during the submarine accumulation of the Lower Silurian Rocks, unbedded volcanic masses have been intruded subsequently, dismembering and altering all the strata with which they came in contact. This hilly district, rising to 1600 feet above the sea, is called

[1] I was directed to this ridge by my friend the Right Honourable Frankland Lewis, who, in despite of a life of labour in the public service, has cultivated with spirit the pursuits of natural history, and is well acquainted with the structure of this county.


CARNEDDAU HILLS, from the S.S.E. near Builth.

C. Murchison delt.

Day & Haghe Lithrs.

Carneddau. It is rocky and rugged on its flanks, exposing fine precipitous faces under Carneddau Castle and Bwlch on the north, at Graig dhu on the south-east; and at its southern end it advances in hard knotty promontories, sloping down from the heights of Gaer-fawr and Tan-y-craig to the left bank of the Wye, opposite Builth. The upper surface of this chief mass of trap is chiefly covered with good pasture, through which the bosses of the rock occasionally appear, and numerous cairns of stone diversify the outline. The following are the chief varieties of the Carneddau trap[1]:

1. Greenstone, fine and coarse-grained, the crystals of hornblende being in some instances distinct.
2. Porphyritic greenstone.
3. Felspar rocks, chiefly granular, but passing into
4. Compact felspar, sometimes very hard. This rock frequently forms the summits.
5. Amygdaloids of various characters, passing into greenstones on the one hand and into porphyritic felspar rocks on the other.
6. Porphyry; some varieties have pink crystals in a dark base of felspar, others contain hornblende.

These rocks are of grey, blue, and greenish colours, sometimes, when the felspar predominates, weathering to dirty white, and the amygdaloids often on decomposing become vesicular. Where the greenstone, containing numerous crystals of white felspar, abounds, as in the bosses between Gaerfawr and Builth, the rocks are very much rounded off, precisely as in the coarse-grained granites of Devonshire and Cornwall[2].

Although I said that the Carneddau Hills are almost entirely composed of trap rocks, yet they throw off upon their sides, and occasionally carry up to considerable heights, dismembered and altered portions of the sandstone, schist, or flag (Caradoc Sandstone, Llandeilo flags). Such examples may be seen near the farm of New House at the height of several hundred feet above the Wye. On the south-western face of the mountain, near the spot called Tan-y-craig, there are extensive quarries, from which Builth has chiefly been constructed. These quarries expose the true nature of this building-stone, which is a variety of bluish grey, volcanic grit. Beneath this lies porphyritic greenstone, bulging out in large spheroidal protuberances.

The hard volcanic grit wraps round the swelling concretionary masses of this trap, and near the junction it is almost impracticable to separate the grit from the greenstone. (See parallel examples in the Corndon and Shelve country, p. 269 *et seq.*) The refuse or top beds of these quarries, however, leave no such doubt, as they are unequivocal Caradoc sandstone, containing several casts of fossils, such as *Orthis Actoniæ*, *O. radians*, *&c.*, though most of them are too imperfect for identification. These beds also fold round protuberances of trap and dip west and south-west.

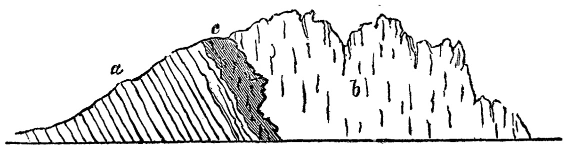
[1] The sketch facing the first page of this chapter, will convey some notion of the outline of the south-eastern corner of this hilly tract. It is taken from the valley of the Wye, about a mile and a half east of Builth. The distant rocks are those of Gaer-fawr and Craig-dhu.

[2] One of the amygdaloids has long been used as a fire stone by the blacksmiths of Builth, another proof, in addition to that of the rock quarried at the Buries near Llandrindod, that felspar which has lost its alkali will resist the amount of heat employed in ovens or ordinary forges.

To the west of these quarries of Tan-y-craig several low ridges (about half the elevation of Carneddau) range in parallel lines from north-east to south-west, some of them terminating in low and narrow bands in the bed of the Wye, others being prolonged about half a mile beyond that river into the knolls of the Park Wells of Builth. These ridges on the north-east contribute to the beauty of the grounds of Pen cerrig and Wellfield. As they are eminently instructive in explaining the intrusive nature of the trap, and present the most unanswerable evidence of that rock having been in fusion when inserted amid the beds of flag and schist, I propose to give a rather full account of this locality, concluding with an account of the probable cause of the mineralization of the springs of the park.

On the sides of the new approach to the house of Pen cerrig the shale is in its usual rotten, shivery condition, containing fragments of trilobites, but is dislocated on approaching the little knoll of greenstone, and within a few yards of it, losing its laminated structure, is converted into a hard, veined, flinty flagstone of light green and black colours, thus:

59.




*a.* Trilobite Shale. *c.* Altered Shale. *b.* Trap.

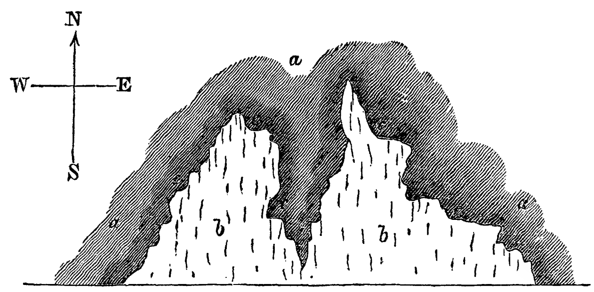
In the quarries of coarse flagstone and wallstone, west of the house of Wellfield, are also evidences of induration and dislocation. Here the trilobite shale, containing some of the largest and finest specimens of *Asaphus Buchii*, is thrown off at an angle of 40° to the west: the stone although slaty on the great scale, breaks into irregular rhombs, and the finely laminated structure is again obliterated. In this case no junction with the trap rock is visible, although we know from the proximity of the summit of the little wooded trap hill which rises up behind this quarry that the intrusive rock is very near at hand[1].

On following these several bands of trap and dislocated Silurian strata as they descend to the south-west, their connection is still more clearly explained. First in some ravines (particularly at Gwern-y-fad), on the sides of which the altered and hardened flags are thrown up into nearly vertical strata between protuberances of trap, and secondly in the bed and on both banks of the Wye. From the west of the hamlet of Gwern-y-fad to the spot called Pen-ddol, the Wye for upwards of half a mile, lays bare a most illustrative transverse section, which is, however, only well seen when the river is low, and then we meet with the following succession in proceeding from west to east.

1. For some distance west of the gorge, black schists containing spheroidal concretions, with *orthocera*, *graptolites*, &c., are thrown off dipping to the west. These beds reminded me of the lowest Wenlock shale. 2. Grey calcareous grit which passes into a coarse rock inclosing fragments of schist, which is much altered, acquiring a conchoidal fracture near the trap, dip 35° north-west. It contains kernels of calcareous spar, and its characteristic fossil is *Pentamerus oblongus*. This band must therefore be classed with the Caradoc sandstone. It dips beneath the shale before described. 3. Irregular bosses of coarse and fine-grained greenstone with a little lime disseminated, thus passing into a finer grained crystalline rock with many veins of white calc spar and crystals of iron pyrites. This trap rises on the right bank of the river and extends to the south-west, constituting the hillocks near the Pump House. 4. In contact with this trap is an altered black flagstone, highly charged with crystals of pyrites, sometimes in geodes. 5. Greenstone, with many veins of carbonate of lime, is

[1] Some of the finest specimens of *Asaphus Buchii* occur in these quarries. The *Trinucleus fimbriatus* and the new species Pl. 25. were found in the highly inclined flagstones of Gwern-y-fad. Notwithstanding the mention of these fossils, the student must not look for any proofs of the *order of succession* in this disturbed tract.

repeated in jagged forms, and followed on its flank by (6) a *porcelain rock* of light colour with many vertical joints which resemble true bedding, but the laminæ of deposit are rarely observable in this altered rock, and when detected they dip north-west at a high angle. This porcelanite is divided into prisms by two sets of highly inclined parallel joints. In one part the beds are twisted round at right angles to the principal strike. 7. Irregular masses, composed of compact felspar, sometimes concretionary, again appear, throwing off indurated and dislocated strata. 8. Light grey calcareous flagstone, slightly indurated in the central beds or those furthest from the trap. 9. Coarse greenstone, resembling syenite, here protrudes in different parts of the bed of the river, and the flag in contact is a lightish blue hornstone irregularly folded over or caught up in the trap. 10. Black flag, slightly calcareous and micaceous, strike south-west and north-east and quite unaltered in the middle. 11. As the strata approach the next boss of trap they become harder, change to a dead dull black, the mica disappears, and large crystals of iron pyrites are abundant; the rock at length acquires a great compactness and specific gravity, yet effervesces briskly with acids, and finally the alteration is still more complete, for the strata are caught up, rolled over, broken, and squeezed in discordant directions, the strike of the indurated and heavy strata being north and south. 12. The greenstone which has caused all this change is projected across the stream in a strong, gnarled, irregular ledge, through which the water has excavated two channels, leaving an island in the centre. The irregular insertion of the trap into the flags can best be comprehended by this ground plan of the two rocks in a part of the bed of the stream.



60.

Some of this greenstone contains carbonate of lime disseminated, and in parts entangles and carries up upon its surface isolated fragments of the calcareous flag, highly indurated, and containing much crystallized iron pyrites with little flakes of anthracite and black calcareous spar.

13. Again the phenomena of alteration disappear in descending the stream, and thirty or forty paces from the intrusive rock the shale is fissile, slightly micaceous, and incoherent, but on coming near another zone of trap which rises into the plantation hillocks on the right bank, the beds first become as thick as tiles (14), and finally, in contact with the greenstone, are united in a heavy, thick-bedded, dull mass, which splits with a conchoidal fracture. 15. The trap rock at this spot is a greyish concretionary greenstone with much iron pyrites and carbonate of lime.

There are two or three other wedges of trap between this projecting rock and the house of Pen ddol, on the sides of which the same appearances prevail, and subsequently the black shale of the district disappears, under the alluvia of the valley of the Wye.

The relations of these alternating bosses of trap and bands of schist demonstrate that the trap rock when in a state of fusion was forced into the beds of schist, altering and dislocating them in the manner above described[1].

[1] Dr. Gilby gave a short account of the "trap and clay slate formation" of this district (1820) in the Edinburgh Philosophical Journal. It contains many good observations, and particularly in reference to the gorge of the Wye above described. "It is curious," he says, "that the slate, or rather the flinty rock at its actual junction with the trap is not stratified, the stratification being only manifest when a little removed from the greenstone. The dip of the slate is everything that is perplexing; sometimes it appears to dip under the ledge . . . . . . In other places the slate seems *shattered and turned about in every direction,* and several times I observed large *patches* of the indurated *schist* completely *contained* in the greenstone." Edin. Phil. Journ. vol. ii. p. 256 and 257. Is it not remarkable that, with such evidence as this, the author could not quite abandon his Wernerian principles? The section which I have given may seem to differ in a few details from that of Dr. Gilby, but I attribute the discrepancy to my having united observations, made on both banks of the river.

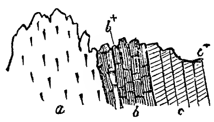
These interesting phenomena do not, however, cease with this transverse section, for we can follow the same masses on their strike to the south-west, through the low hummocks on the left bank of the Wye till they disappear at the Park Wells, where they clearly explain the means by which those powerful mineral waters are formed in the laboratory of nature.

*Park Wells.*—The trap of this district appears for the last time on the south-west in a low knoll north-west of the Pump House. It is a coarse greenstone containing many crystals of iron pyrites. The Pump House stands upon this rock, but the mineral water rises from the adjoining schist, which is thrown up into vertical strata striking north-east and south-west, is highly charged with crystals of iron pyrites, and has in parts, veins of quartz crystals and calc spar. The natural decomposition of the pyrites which must be constantly going on by the percolation of water along the planes of these vertical beds, sufficiently accounts for the origin of these strong sulphureous waters, a natural process which has been already sufficiently explained in the account of the origin of the Cheltenham waters. (See p. 34 *et seq.*)

Within a very few paces of the highly sulphated spring there is another source in which no sulphur exists, but in which slight chalybeate properties are alone distinguishable.

The position of the rocks readily explains this fact.

Builth Wells. 61.



*a.* Trap. *b.* Altered flags. *c.* Unaltered flags.
*b**. Strong saline, issuing from the altered flags.
*c**. Slightly saline water issuing from the schist.

The sulphated spring issues from those highly pyritized and altered flagstones in immediate contact with the trap, and from the *vertical* position of the strata and their hard nature it is quite manifest that such as the spring has been from the moment at which it issued to the atmosphere, so it must run on unchanged as long as pyritous matter remains in sufficient abundance to impregnate it; for the column of sulphurous water rises to the surface in a natural conduit (*b*), which has been rendered impervious upon its sides by the induration of the mineralized strata.

At a few paces further from the trap are other strata (*c*) less altered, containing much less pyrites, and the water rising through these is very slightly saline. In the transverse section of these same beds in the Wye we have shown how frequently and rapidly the mineral characters of the strata change in passing over their vertical edges, and consequently there can be no difficulty in imagining, how very different may be the contents of springs which issue within a few feet of each other.

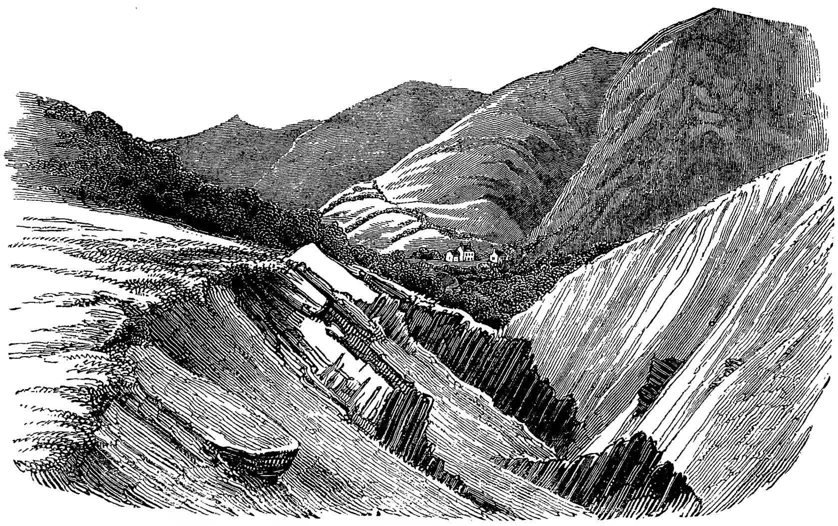
I use the term *pyritized* in reference to these altered rocks in contact with the trap which contain numerous and large crystals of iron pyrites (sometimes also in flattened nodules of one and one and a half inch in diameter), because it appears to me that the

accumulation of the mineral in these particular points is due to the same agency by which the strata were dislocated and altered. Sulphuret of iron is, doubtless, generally diffused through almost every formation ; but in this region I never observed it in crystalline bunches, except at the junction of the trap with the altered rocks.

If, therefore, it has been inferred that the mineral veins of the district of Shelve in Shropshire resulted from volcanic action, so is it inferred that the numerous mineral sources which issue from the flanks and extremities of this disturbed tract, at Llandegley, Blaen Eddw, Llandrindod and Builth, are due to a similar cause.

The great diversity of composition of the waters which issue from contiguous springs at Llandrindod, is to be accounted for in the same way as at the Park Wells near Builth. These shades of difference, however unimportant to the geologist, who simply endeavours to expound the mode of action by which they have been evolved, are points of high interest to the chemist and of great value to mankind, some of the least perceptible of these ingredients being of great importance in their effects upon the human body. With the permission of my friend Dr. Daubeny, I therefore annex in the Appendix his able analyses of the waters of Llandrindod, Builth, and Llandegley[1].

[1] Dr. Daubeny recently undertook this examination with the view of ascertaining whether all these mineral sources which issue from strata known to have formed beneath the sea did not contain iodine and bromine, which modern French chemistry has shown to be of marine origin. These labours have confirmed expectations founded upon just philosophical principles, and have by mineral tests completed to a great extent, the proofs of the submarine formation of those strata in which the research of geologists has pointed out the remains of so many marine animals. To render, however, this argument quite valid, all strata inclosing marine shells ought to contain iodine, bromine, and muriate of soda.



62.

*View near Llanwrtyd Wells, from a drawing by Mrs. Traherne.*

# CHAPTER XXVII.

## SILURIAN ROCKS OF BRECKNOCKSHIRE.

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*Silurian Rocks in Brecknockshire, including the anticlinal Ridge of Brecon.—Trap and altered Rocks and Mineral Waters of Llanwrtyd.* (Pl. 31. figs. 1, 6, 7, 8 and 9.)

ON consulting the Map it will be seen that Upper Silurian Rocks undulate along both banks of the Wye between Builth and Erwood. They are usually in discordant positions on the opposite banks of this river, which thus runs in a fissure transverse to the line of elevation, and similar to those fractures before alluded to, in which the rivers Severn, Onny, Teme, and Lugg, have their course[1]; for like them, this fissure of the Wye proceeds from north-west to south-east and *at right angles to the strike* of the strata. Among the numerous dislocations by which the form of the valley was predetermined, none are more instructive than those near the boundary between the Old Red Sandstone and the Silurian System. Ludlow Rocks with their distinguishing fossils mount up into the hills of Upper Llangoed and dip to the *south-east* under the Old Red Sandstone, whilst at Llanstephan, on the Radnorshire bank, similar beds are thrown

[1] pp. 230 to 240.

to the *north-east* beneath the same red sandstone. At Erwood, not a mile from the eastern boundary, the bed of the Wye exhibits great confusion, a narrow wedge of red sandstone being there dovetailed between masses of Ludlow rock. That this patch of sandstone does not belong to the Silurian System is clearly explained by ascending the hills to the south-west, where a promontory of Ludlow Rocks is found, constituting a distinct prolongation of the Silurian frontier. The Silurian strata, in fact, dip both to the north-west and south-east, constituting a marked anticlinal ridge, which throws off the Old Red Sandstone on each flank; and hence the narrow tongue of that rock at Erwood is simply one end of the wide area of Old Red Sandstone which occupies the wilds of Mynidd Epynt. (See Map.)

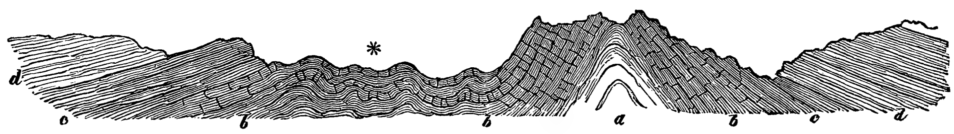
*Brecon anticlinal.*—The Ludlow rocks form the above promontory amid the Old Red Sandstone, extend in highly disrupted masses from Erwood, on the Wye, to Corn-y-fan, six miles north-west of Brecon, where they terminate in a narrow point after a course of about ten miles. This remarkable ridge offers, perhaps, the best type of the Ludlow formation to the south of the Wye. It does not consist of one continuous range, as I was at first disposed to think, but of large masses which are often disjointed, trending in slightly divergent directions, and sometimes completely separated by great transverse intervals occupied by Old Red Sandstone. (See map.) These elevated rocks constitute the mountainous hills or wild moorlands of the Graig, Llan eglwys, Ysgwidd-hwch, and Castel-madoc, including Gaer-fawr and Altt-fawr, Castel rhiwan-nest, Mynidd-bach and Corn-y-fan, and rising to heights varying from 1200 to 1500 feet above the sea, are prominently distinguished by their grey surfaces from the red lands through which they emerge. The mean strike of the strata is from 30° north of east to 30° south of west, though there are considerable deviations from this direction in the different masses. Thus, in the hills near Crickadarn and the Wye, the strike is nearly north-east and south-west. In Mynidd-bach and Corn-y-fan, the south-western extremity, it is E.N.E. and W.S.W.; whilst in several of the smaller intervening masses it is east and west. These differences in direction are the evidences of powerful transverse dislocations along this anticlinal line, and afford the most convincing proofs that the strata so affected have been forced up with intense violence.

The picturesque and rocky point of Corn-y-fan, where the Ludlow rocks finally subside, is a striking example of the truth of this remark. That rock presents on one face an inclined plane dipping to the north-east at 33°, but in a few yards, or its extreme point, the inclination changes to the south-west, in both cases the strata of the Ludlow formation passing conformably beneath the Old Red Sandstone; whilst on the south-eastern face is a broken escarpment, probably due to the narrow form and sharp inclination of the elevated mass, for in the bed of the adjacent brook, which is parallel to it, and near the farm of Neuadd, the Old Red Sandstone is thrown off to the S.S.E. at the very high angle of 80°. (See Pl. 33. f. 9.) As they approach the western extremity, the elevated masses of Upper Silurian rocks are most affected

by the transverse breaks before alluded to, three of which are parallel, occupied by the streams Yscir-fechan, Yscir-fawr, and Honddhw, tributaries of the Usk. Wherever the Silurian strata compose a distinct anticlinal ridge, as at Mynidd-bach, near Corn-y-fan, Pl. 33. f. 8., they are symmetrically arranged on each side of the axis, —the Upper Ludlow rocks graduating on both flanks into the Old Red Sandstone, through fissile, yellowish sandstones, which represent the beds of Downton Castle, p. 197. Similar strata of Upper Ludlow Rock occur in the dome-shaped hill of Castell Rhiwannest, though their passage upwards is well seen only on its north-western slopes, the Old Red Sandstone on its western face being rendered unconformable by a powerful fault.

The hills of Castel Madoc on the left bank of the Honddhu present a fine development of the Upper Silurian Rocks, expanded over a width of about two and a half miles. On first viewing the outline of these rocks, the geologist would imagine that the lower and dome-shaped masses in the centre must necessarily be composed of underlying strata, like the centre of the Ludlow promontory (Pl. 31. f. 5.), or still more like the Valley of Woolhope near Hereford, hereafter to be described (Pl. 36. figs. 9 and 10.), where the central dome consists of Caradoc sandstone. But, on examination, we discover two parallel lines of elevation, by which strata of the same age are repeated in separate anticlinal forms on both sides of a central depression, dipping *inwards* as well as *outwards,* and thus rendering the low inner domes*, portions of the *youngest*, and not of the oldest strata as at Ludlow and Woolhope. (See Pl. 31. f. 6. and this wood-cut.)

Allt-fawr. 63.




*a.* Lower Ludlow Rock. *b.* Middle Ludlow Rock, including a calcareous band with *Terebratula Navicula.* *c.* Upper Ludlow Rock. *d.* Old Red Sandstone.

As these undulations are at some points rapid, the strata being disposed at high angles so as to meet in sharp ridges and at others form domes, and as on the outer flanks the beds pass beneath the Old Red Sandstone at gentle angles, we have abundant facilities for determining the complete succession of the strata. The external faces of the outer ridges are composed of the true Upper Ludlow Rock, and contain its characteristic fossils, including *Leptæna lata, Cypricardia amygdalina,* with *Orthocerata,* &c.

These Upper Ludlow Rocks, which are of considerable thickness, pass upwards into ordinary marls and tilestones of the Old Red System. They are underlaid (particularly along the crests of the sharp ridge of Allt-fawr) by a thin band of impure limestone, made up almost exclusively of the small *Terebratula navicula,* which forms so constantly the roof of the limestone of Aymestry. This small shell is, therefore, a most valuable guide in marking the place of this subdivision or central part of the formation, even where

the great mass of calcareous matter and some of the characteristic shells, as *Pentamerus Knightii*, have disappeared. Again, beneath these calcareous beds, are fissile and flaglike strata, perfectly resembling those Lower Ludlow Rocks which form the base of the mountains of Radnor Forest. In short, nearly all the well-known types of the formation may be here detected, the only essential differences being a less proportion of calcareous matter, and the superior hardness, as well as more slaty structure of the stone.

Let those who doubt of the practicability of drawing a well-defined boundary line, between the Silurian and Old Red Systems, place themselves upon this narrow ridge of grey coloured rocks, and contrasting their colour and external features with the surrounding expanse of red lands, they will, at once, admit that no two formations can be more neatly separated. (See Pl. 33. f. 6.) This observation is indeed of general application and admits of no modification, for it may truly be said that the physical demarcation is clear in all districts where the surface is free from drifted materials[1].

The Brecon anticlinal exhibits in its sharply inclined, undulating, and dislocated ridges, many beautiful examples of *symmetrical joints*, the direction of which changes (as in the Ludlow promontory) with every variation in the strike of the strata. As the rock is here well exposed and more compact than usual, there is perhaps no situation where symmetrical jointed structure can be better studied or more clearly distinguished from those cracks and fissures which have resulted from disturbance. On this point, however, I must refer the reader to Chapter 20, in which he will find a general explanation of my views; some apposite remarks are also thrown out in various other places, particularly in the ensuing chapter, in describing Noeth-grüg, Caermarthenshire; while those who wish to go into the details must consult the Appendix[2].

The great dislocations, however, which occur throughout this promontory form its chief attraction, since the magnitude of the cross fractures which have dissevered it into a number of separate masses, prove that the upheaving force must have operated with intense violence.

[1] For an account of the drifted materials superficially strewed over parts of this region the reader is referred to the concluding chapters; but I cannot avoid remarking that the phenomena which I have found to prevail in all elevated tracts are here most strikingly displayed. Not a single boulder is to be found amid the dome-shaped or sharp ridged hills of this axis of elevation, though there are within their range numerous hollows and deep cavities ready formed for the reception of such drift, whilst broken materials, derived from these very hills, are piled up, sometimes in enormous masses, on the exterior slopes of the elevated chain. See many of the hills between Lower Chapel and Brecon, &c.

[2] Anxious to examine this ridge with one who has thrown so much light on jointed structure, I was delighted when Professor Phillips resolved to look at this anticlinal on his way from Bristol to North Wales (1836), and I met him at Brecon. The portion we examined together, lies to the west of the river Honddhu. I owe much to my friend's suggestions on that occasion, and had great reason to admire the precision with which he observed the phenomena. I have only to regret that he had not leisure to examine the north-eastern range of the promontory, extending from Castel Madoc to the Wye, where the best and most symmetrical joints are developed. Geologists look forward with anxiety to the enlarged publication of his views on this difficult subject, knowing that their conclusions must be regulated by a multitude of correct observations.

By inspecting the map it will be seen that this dislocated spur of elevation is precisely coincident with the axis of the Ludlow promontory, the point of which is forty-one miles distant from *Corn-y-fan*, while at *Old Radnor*, midway between these extreme points of the line of elevation, is a ridge of volcanic rock, the eruption of which enables us satisfactorily to account for the remarkable phenomena above described, and to connect them with those detailed in the nineteenth and twenty-fifth chapters.

Returning to the gorges of the Wye, whence we traced the anticlinal, the Ludlow rocks on the right bank of that river exhibit partial dislocations, frequently diverted from their true bearing, though at low angles of inclination; but quitting that valley, and following them as they fold round the Old Red Sandstone of the Mynidd Epynt, we first find the strata inclined to the S.S.W. in the hills of Gwendwr and Pant-y-llyn. They thence bend round by Pant-y-garreg and Cwm-nant-gwyn, until they regain the prevailing north-east and south-westerly strike, and dip below the Old Red Sandstone. From the hill of Moel-fre, near Builth, they begin to strike persistently to the south-west, and constitute that extraordinarily straight escarpment, the north-western boundary of the wilds of Mynidd Epynt and Mynidd Bwlch-y-groes, which is prolonged into Caermarthenshire. In all this range the Upper Ludlow Rock is clearly defined, by its gray colour and characteristic fossils, and it is overlaid conformably at many points by the old red tilestones. There are, however, few places where the mineral character or fossil contents of the underlying strata enable us to separate them into sub-formations with the same distinctness as in parts of the Brecon anticlinal.

Of the many transverse sections which may be made from the junction of these strata with the Old Red Sandstone of the Mynidd Epynt to the base of the Upper Silurian Rocks, I will cite only two cases; first, that on the sides of the high road from Brecon to Builth in descending from Llang-y-nog into the valley of the Wye through the Cwm-nant-gwyn; and secondly, that in the Cwm-craig-dhu, exposed in the new road from Brecon to the valley of Yrfon, because they can be well seen by the traveller. In the first, the following strata occur in descending order:

Hard, indigo grey, slightly calcareous and micaceous flagstone of good quality, containing orthocera and other organic remains of the Upper Ludlow Rock.

Sandy beds, of dirty green colours, finely laminated.

Bluish grey, slightly calcareous rock, surface on weathering friable and porous, with ferruginous casts of fossils, including *Calymene Blumenbachii, Serpuloides longissima, Orthocera, Avicula reticulata, Pleurotamaria*, and *Turbo corallii*, the coral investing these two shells being of the same species as at Ludlow, distant between forty and fifty miles.

Thicker bedded, indigo grey, hard stone, with flattened orthocera, some apparently of the pear-shaped species, *O. pyriformis*.

Beds with the *Terebratula navicula*, marking the place of the Aymestry limestone as in the Brecon anticlinal.

The above subdivision is exposed in successive layers about 500 feet thick, and represents the Upper and Middle Ludlow Rocks. The beds dip 16° to 18° south-east. They are underlaid by shale disposed in large concretionary masses, and from beneath these rise other beds of strong flags, somewhat calcareous and of bluish grey colours, which mount into the hill of Rhiw-frenin, and contain many flattened orthocera and other fossils of the Lower Ludlow Rock. The latter beds occupy a considerable thickness in the escarpment of Rhiw-frenin, and at the bridge they are underlaid by stratified masses of shale and schist, occasionally putting on a very imperfect slaty cleavage, and weathering into numberless small angular

shivery fragments. In their prolongation to the north-east, at the Hennalt and New Hall, these beds are quarried for tiles and coarse slates. They are again underlaid by other masses of dull grey, non-micaceous perishable shale, which has a tendency to spheroidal or large concretionary structure, and these range over the undulating grounds south-east of Builth. This lower portion of the Upper Silurian Rocks dips at a less angle than the higher, seldom exceeding 8° or 10° to the S.S.E.

The transverse section of Cwm-craig-dhu, descending from the Mynidd Epynt to the banks of the Yrfon, is in some respects better than that of Cwm-nant-gwyn. The bottom beds of the Old Red Sandstone, consisting of red and green marls with micaceous flags (tile stones), and dipping 30° to the south-east, pass downwards into the intermediate grey rock, the "Downton Castle building stone." Beneath is a full succession of the Upper Ludlow strata, charged with abundant casts of fossils, overlying, indigo-coloured calcareous flagstones, like those of Rhiw frenin. These are similarly underlaid by sandy shale and schist, weathering into rotten and fissile fragments, containing the *Cardiola* of the Lower Ludlow Rock, with some beds of harder flagstone, slightly micaceous and calcareous. The inclination of the lower beds gradually increases from 40° to 60°, and they repose upon black shale of great thickness, weathering to small shivery fragments (rotch), but no clear section is obtained till the banks of the Yrfon are reached, when the shale is highly inclined, vertical, and dislocated. (See Pl. 33. f. 6.)

Few of these lower beds have sufficient cohesiveness to afford building materials, but in the bed of the Yrfon, between Tafarn-y-pridd and Llangammarch, the schists contain a few concretionary courses of dark grey calcareous flags, with thin beds of conglomerate.

### "*Lower Silurian Rocks.*"

The underlying or Lower Silurian Rocks are ill developed in Brecknockshire, for as soon as the protruded mass of trap rocks described in the last chapter, disappear near Builth, these older strata are no longer seen rising from beneath the cover of Upper Silurian Rocks. A few beds of Caradoc sandstone accompany, it is true, the black Llandeilo flag upon the Wye, and occupy the low hillocks between its right bank and the Park Wells, the relations of which have been pointed out in the last chapter. With this exception, all the district between the escarpment of the Upper Silurian Rocks and the boundary line of the slaty rocks of the Cambrian System, is occupied by undulating hills of perishable schist and shale, with very rarely a course of sandstone and grit. The latter, however, occur in the hill of Garth, forming strong-bedded quartzose conglomerate, grit, and sandstone in nearly vertical strata, extending for about two miles to the N.N.E.; and again, at Dol-aeron, are beds of bluish grey, flag-like building-stone, dipping north-east 20°. In these quartzose rocks I could detect no fossils. They may, indeed, belong to the Lower Silurian division, but from their mineral characters I should be disposed to place them in the Cambrian System. The subsoil of all the sterile tract watered by the Chwefrw, the Cammarch, the Dulas, and the Cwm-dwr (tributaries of the Yrfon and Wye), consists of rotten shale with scarcely the vestige of a solid bed of stone; so that this part of Brecknockshire offers a strong

analogy to the north-western uplands of Radnorshire, where it has been shown there are no traces of the Caradoc sandstone and Llandeilo flags.

"*Cambrian Rocks.*"

The Upper Cambrian or slaty greywacke group in Brecknockshire is simply a prolongation of those rocks which have been described as advancing in Radnorshire to the left bank of the Wye, in the hills of Dolevan, Rhiw-graid, and Gwastaden. Their south-eastern frontier runs along the hills of Pen cefn-ty-mawr and Alt-y-clych, their summits being marked by quartzose conglomerates like those of Dolevan. As they trend to the south-west, the quartzose grits thin out, but reappear in the high hills of Pentwyn and Esgair-davydd, south-west of Llanwrtyd, whence they are prolonged at intervals into Caermarthenshire. These quartzose grits are subordinate to a thick assemblage of coarse and imperfectly formed slates, which are displayed on the sides of the transverse and parallel gorges by which the streams of the Chwefru, the Dulas, the Cammarch, the Cnyffiad, and the Yrfon flow from the higher and western regions of Brecknockshire. A slaty cleavage, the planes of which dip at high angles to the north-west, is, for the most part, distinctly impressed upon these old rocks, and further to the north-west they graduate into true roofing slates. Though organic remains are very rare, I have discovered imperfect casts of them in the grits near Llanwrtyd.

An important feature in the arrangement of the rock masses of this country is, that the Cambrian System and older slates are thrown over with an inclination to the north-west, and sometimes at high angles. This phenomenon of the older or Cambrian rocks being found in a position discordant to those of the Silurian System, has been before alluded to, p. 309, and is observable along the line of junction in the counties of Salop, Montgomery, Radnor, and Brecon. It is, indeed, precisely what must have resulted from those elevations by which the Lower Silurian Rocks have been developed in anticlinal ridges, and have thus thrown off on both sides the Upper Silurian Rocks, which on one flank, are thus necessarily brought into abrupt contact with the strata of the older system. In Caermarthenshire and Pembrokeshire, however, we find, that where other parallel lines of elevation affecting the Lower Silurian Rocks have taken place near the frontier of the Cambrian rocks, there are, as in the example of the Berwyns, p. 308, indisputable evidences of a passage from the one system into the other; and hence the great break between the Silurian and Cambrian Systems, marked in many previous sections like that between the New Red and Carboniferous Systems, is to be only classed among limited phenomena. (See also remarks on the passage from the New Red into the Coal Measures, pp. 54, *et seq.*)

64.

*Porphyry intruded in the schist near Llanwrtyd, from a sketch by Mrs. Traherne.*

(P. Porphyry.) (A S. Altered schist.)

## *Trap and Altered Rocks in Brecknockshire.*

With the exception of the small knolls near Builth already described, no observer had previously noticed any mass of trap rock in Brecknockshire. Having heard of the mineral waters of Llanwrtyd, I conceived that as similar springs in Radnorshire and at Builth uniformly issued from altered strata in contact with trap rocks, the same phenomenon might be repeated near this spa; and on visiting it, the inference proved correct. I found a line of intrusive rock, about three miles in length and half a mile in its greatest width, running, like the trap ridges of Radnorshire, from north-east to south-west. A narrow and deep dell, through which flows the rivulet Cerdin, divides this elliptical-shaped ridge into two mountains, Caer-cwm and Garn-dwad, each about 1600 feet in height. At the north-eastern extremity of Caer-cwm, trap is seen, for the last time, on the banks of the little stream Nant-einon, alternating in thin courses with slaty schists; whilst at the south-western end of Garn-dwad the trap crosses the Ithon between Llanwrtyd and the mineral spring, near a boss of rock called Gwern-goch, upon the right bank of that river, and near the farm-house of Dol-y-dymmor. In this ridge of Garn-dwad and Caer-cwm the predominant character of the trap is porphyritic, and the following varieties occur:

1. A rock, having a base of greenish grey colour, composed apparently of an intimate mixture of compact felspar and hornblende, spotted white, probably by a separation of felspar from the compound base.

2. Coarse rock of granular felspar, with minute crystals of common felspar, containing a number of minute grains of quartz.

3. A variety of the same, containing many well-defined crystals of felspar in a greyish granular base, and a few small elliptical cells filled with green earth.

4. Dark grey and green, concretionary, compact felspar.
5. Greenstone, highly crystalline, both fine and coarse-grained, and sometimes very hornblendic.
6. Greystone, or grey granular felspar, intimately mixed with hornblende and a few crystals of carbonate of lime.
7. Amygdaloidal trap, cellular on the weathered surface.

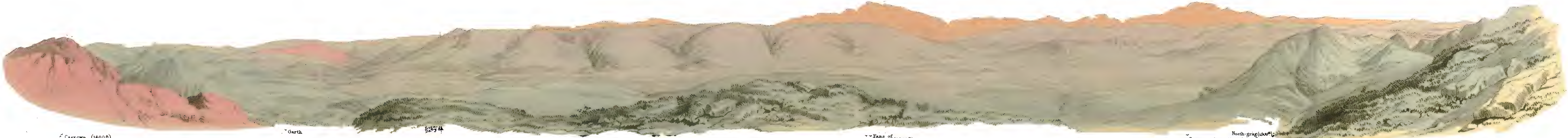
The greenstones are best seen near Pen-y-banc, and the more porphyritic rocks occupy the centre of the hill. Associated with a porphyritic greenstone, in the bed of the Yrfon at Dol-y-dymmor, is a greenish grey, close-grained amygdaloid, having the cells filled with calcareous spar, generally coated with pellicles of green earth, and varying in size from mustard-seeds to almonds. In some cases the stratified rocks in contact appear to have undergone a kind of "*boursoufflure*," and are scarcely to be distinguished from the amygdaloid. On the sides of the principal ridge of trap, the changes produced in the vertical and dislocated strata are numerous and clear. On its lower flanks and south-western extremity near Pen-y-banc, the trap is coated with a thin and broken covering of schist, which is silicified or in the state of hornstone, highly translucent at the edges, of a scaly fracture and dark grey colour with cloudy streaks, as if formed by an imperfect separation of hornblende. Other varieties are black Lydian stones, ringing under the hammer, and splitting with a fine conchoidal fracture; some of them containing a number of bright metallic spots, probably oxide of iron. The upper parts and summits of these hills exhibit numberless rugged and irregular bosses of trap, sometimes carrying up fragments of altered or indurated schist, which occasionally contains crystals of carbonate of lime irregularly disseminated, giving to the rock a pseudo-porphyritic structure. (Sides of Caer-cwm.) The flanks of the hills, where partially eroded, offer beautiful examples of contorted, broken, and altered schists, particularly near the little transverse valley of the Cerdin, and about half a mile north-east of the farm of Pen-y-banc. Mrs. Traherne (being on a visit to the baths in 1833) has kindly enabled me to present the reader with a perfect view of the relations of the trap to the broken strata. (See p. 343.) Irregular knobs of trap penetrate the schist, which is dislocated, shattered, and bent. Much iron pyrites occurs near the point of contact; the shale is indurated and exhibits polished surfaces with some quartz and traces of plumbago (*carburet of iron*). A little further down the side of this abrupt ravine, the schists weather to a whitish colour, in the same manner as some of the killas of Cornwall. On the other side of the gulley, and removed from the ridge of trap, the slaty schists are no longer contorted or broken, but rise with perfect regularity, having a slaty cleavage, the planes of which dip north-west 65° to 70°. (See the previous wood-cut.) In the little comb of Nant-yr-odyn, north of the gorge of the Cerdin, the black and highly inclined shale has been penetrated by galleries in search of coal; the mania for this speculation, to which I have already so much alluded, appearing to strengthen in proportion to the impossibility of success; these stratified, slaty deposits being unquestionably a part of the Cambrian System, for to the west of this ridge they pass into true roofing slates.

Whilst the porphyritic trap occasionally peeps out in rugged bosses along the summits and sides of the hills of Caer-cwm and Garn-dwad, the little transverse dell of the Cerdin lays bare the true nature of this nucleus in a rock called Craig castell, which towers above the left bank of the stream. This precipitous cliff is a porphyry, the exterior of which is black, but the interior is grey compact felspar, with minute white crystals of common felspar. It is arranged in slender four-sided prisms, from 25 to 30 feet in length by 5 or 6 inches in diameter, and crossed by transverse joints, the planes of which dip to the north-west. The large and broken masses below are partly of the same rock, partly of other varieties. This is one of the most impenetrable rocks met with in the whole of the country I examined, being very analogous both in composition and relations to some of the porphyries of Snowdon, Cader-Idris, &c., and like them its forms arise from joints, separating the mass into four-sided prisms. As the trap of the mountain of Caer-cwm tapers away to the north-east and finally ceases near Blaen-einon, so that of Garn-dwad thins off to the small protuberances and bands which traverse the Ithon at Llanwrtyd. The bed of this river offers many beautiful examples of highly silicified and indurated strata in contact with trap, strictly according with those described on the banks of the Wye near Builth. The analogy is also rendered quite striking by sulphureous mineral waters issuing from the adjoining shale; and, judging from the appearance of the veined and altered strata which are exposed on the sides of these trap hills, we can hardly doubt that the mineralization of this spring is due to the decomposition of sulphuret of iron, which has been largely accumulated at some of those points where the trap has been intruded into pyritous shale, in the manner similar to that pointed out at the Park Wells near Builth, and at Llandrindod. These waters of Llanwrtyd have not hitherto been completely analysed, but it is sufficient for my present purpose to state that they are sulphureous and slightly saline.

Lead ores occur in the chain of slate hills on the west, and veins of copper have latterly been discovered. These veins lie far within the Cambrian frontier. With respect to the precise age of the altered strata of the Llanwrtyd hills it is difficult to speak with confidence, since very slight traces of organic remains have been hitherto observed; yet, judging from analogy and the range of the associated rocks, I believe they may be placed in the upper division of the Cambrian System. (See next chapter for an account of these rocks in Caermarthenshire.)

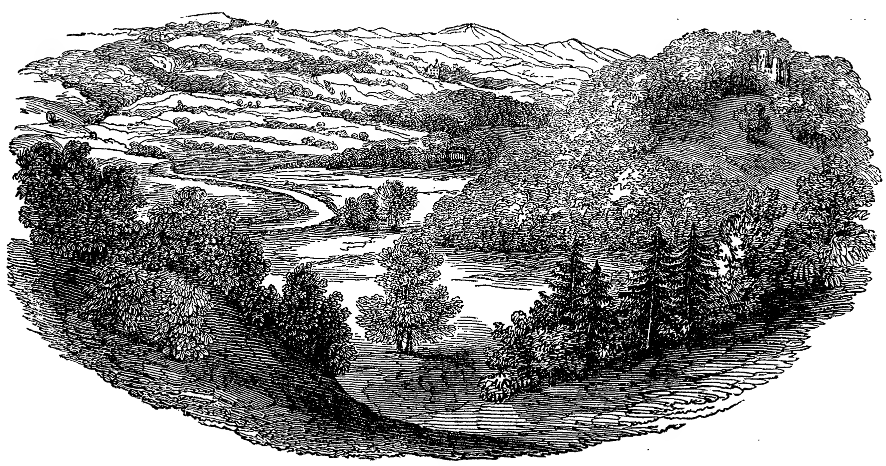
I cannot more effectively convey to my readers a clear notion of the arrangement and succession of the strata in Brecknockshire and the adjacent counties of Radnor and Caermarthen, than by annexing a semi-panoramic view, taken by Mrs. Traherne, from the mountain of Esgair davydd, south-west of Llanwrtyd. The spectator is placed on the old slaty rocks of the Cambrian System, and looking E.N.E. and S.E., his range of vision embraces the outlines of two great systems which it is my object to illustrate. In the distance is the Old Red Sandstone, occupying the highest mountains of

South Wales (see p. 169, *et seq.*), and in the middle ground the Silurian System, appearing prominently in the escarpment of Mynidd Epynt, whence it extends north-eastward to Radnor Forest, and south-westward into the hills near Llandovery. The valley in which the Yrfon and the Wye meander, through beds of soft schist and shale, is well expressed by the artist; while the bright red colours indicate the ridges of eruptive rock which have been described in this and the preceding chapter.




Cambrian System. | Silurian System. | Old Red System. | Trap and altered Rocks.

PANORAMIC VIEW FROM THE HILLS SOUTH WEST OF LLANWRTID BRECKNOCKSHIRE.



65.

*Vale of the Towy, and Golden Grove, as seen from Dynevor Park near Llandeilo, sketched by Mrs. Murchison.*

# CHAPTER XXVIII.

## CAERMARTHENSHIRE.

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*Course of Upper and Lower Silurian Rocks maintained by superposition and organic remains.—Great changes in lithological structure.—Lower Silurian where best developed—in parts affected by slaty cleavage.—Fine exhibition of Llandeilo flags, their passage into Cambrian System.—Change of strike as the strata pass into Pembrokeshire.—Cambrian Rocks.—Trap and Altered Rocks.—Mines, &c.* (Pl. 34. figs. 1 to 11.)

### *Silurian Rocks in Caermarthenshire.*

UPPER Silurian rocks, similar to those of Brecknockshire, are prolonged into Caermarthenshire with precisely the same relations to the overlying red sandstone; whilst the Lower Silurian Rocks, of which the traces are so imperfect both in Radnorshire and Brecknockshire, reappear in as great force as in any parts of Salop, Hereford, or Montgomery; the Llandeilo flags, in particular, having their fullest development in this and the adjoining county of Pembroke. A good natural transverse section of the upper group is exposed in the narrow valley of Cwm-dwr[1], already noticed in describing the tilestones of the Old Red System.

[1] In the prolongation of the escarpment of Mynidd Epynt and Mynidd bwlch-y-groes. See p. 181 *et seq.*

On both sides of the ravine, these tilestones inclined 60° and 65° to the south-east pass downwards into grey-coloured rocks. The junction is well observed to the west of Horeb chapel, near which the Upper Ludlow Rock, rising from beneath the tilestones, ascends into the peaks called Cerrig-bw-bach. The ends of the underlying strata are visible on the north side of the road, but are more clearly exposed on the opposite or south-western bank in small parallel ridges separated by combs, and the decomposing ends of the beds which protrude through the grass contain a few fossils. As the angle of inclination increases, the strata pass down into others, charged with casts of large *orthocerata, corals,* &c., and these are succeeded by dark grey flagstones and coarse slaty beds exposed in the longitudinal depression of Cwm-meirah and in the opposite bank of the stream near the half-way house. Among the fossils at this spot are *Asaphus caudatus, Productus depressus* (var.), *Atrypa affinis,* and many *corals,* &c.

These lower strata are still more highly inclined, than those of the Upper Ludlow Rock and Old Red Sandstone, for they become absolutely vertical, and in some parts are even so bent over as to dip to the north-west, apparently passing under the Lower Silurian Rocks which flank them in that direction. There can, however, be no doubt that the beds are only partially inverted, since there is the clearest evidence, that the strata and their fossils which lie between this spot and Llandovery belong to the Lower Silurian Rocks. These beds, where vertical or most bent, are broken through by numerous, parallel, vertical, small joints, transverse to the strike, the interstices being often filled with quartz crystals[1]. The fossils on the whole agree with those of the Lower Ludlow Rock, although there are one or two species not found in Shropshire, an addition to be expected in the same formation at distant points. These strata are succeeded by beds of black shivery shale, which, though generally perishable, have occasionally (as on the south-eastern face of the adjoining parallel ridge of Cefn-erthan) so fissile a structure, as to have been quarried for rough slates. They occupy precisely the same position as the coarse slates of Hennalt near Builth, and complete the parallel between the Upper Silurian Rocks of the Cwm-dwr and those on the Wye. (See previous chapter.) These rocks range to the south-west along the escarpment of Mynidd-myddfai, and are well seen in the transverse section of the gorge of Pont-ar-llechau (banks of the Sowdde river, Pl. 34. f. 5.). The junction beds beneath the Old Red Sandstone are grey, fine-grained, very slightly micaceous, hard sandstone, of conchoidal fracture (the corner or building stone of the district), which passes down into thinner flaggy beds with casts of fossils, succeeded by strata of compact sandstone, again alternating with other flag-like fossil beds. These beds in the gorge of Pont-ar-llechau dip at angles of 70° and 80° beneath the Old Red Sandstone, and are in parts much affected by a slaty cleavage, occasionally so complete as to pass through the laminæ of deposit and cut completely through the organic remains. Ludlow rocks possessing all these mineral characters are underlaid on the sides of the road between the Cwm-dwr and Llandovery, and in the tract between that road and the river Sowdde, by arid, sandy shale, usually devoid of fossils. It generally folds over in undulating and sometimes in large sub-concretionary masses, in which lines of true stratification are exceedingly obscure. At Pwll-calch, near Myddfai, the upper part of this shale contains a stratum sufficiently calcareous to have been burnt for lime. The mass lies in vertical strata, which strike 30° south of west and 30° north of east, and is from 30 to 40 feet wide[2].

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[1] This is one out of a multitude of examples clearly exhibiting a jointed structure, the direction of the joints changing with every change of the strike.

[2] My attention was first called to this small patch of limestone by Mr. W. Rees of Llandovery, to whom I am obliged for several good hints respecting the topography and structure of this neighbourhood.

The stone is of a dark grey colour and of sub-crystalline structure, penetrated by many veins of white calcareous spar. The fossils found on the weathered surfaces at this spot and in the shale of Tynewidd, not far distant, are principally those of the Wenlock formation. Among them are *Spirifer radiatus, Productus depressus, Orthis spinosa, Terebratula leviuscula, T. crebricosta, Lingula lata, Orthoceras annulatum,* and several corals of the formation.

There can consequently be little doubt that this calcareous band, slender as it is, represents truly the Wenlock limestone, a fact of high interest, as we have been unable to mark the exact place of this rock in the strike of the Silurian System since we took leave of it at Old Radnor, distant from this spot about thirty-six miles. Again, slight traces of this limestone appear on the banks of the Sowdde between Pont-ar-llechau and Rhyd-sant, but they are the last signs of any *calcareous beds of this age* in the south-western prolongation of the Silurian rocks of Caermarthenshire. At Pwll-calch the calcareous mass is flanked by walls of a hardish, flaglike, slightly micaceous sandstone of a dingy grey or green colour, traversed by veins of white crystallized quartz; proving how very materially the strata have changed their lithological characters since we took leave of them in Salop and Hereford.

From the right bank of the river Sowdde, and thence to the south-west and west below Caermarthen, the Upper Silurian Rocks thin out considerably, and are quite incapable of subdivision; for although a partially fossiliferous grey sandstone, which may be termed Ludlow rock, rises out from beneath the tilestones of the Old Red Sandstone, there is little subjacent schist and shale to represent the Lower Ludlow Rock, and no trace of subordinate limestone. This member of the Silurian System in Caermarthenshire is so unlike the beds of the same age in Salop and Hereford and Radnor, that what in these three latter counties is called a *mudstone,* is here represented by a hard compact sandstone.

Pursuing these Upper Silurian Rocks along the ridge of the Tri-chrug, we come to the transverse dell by which the little river Cennen flows into the vale of the Towy, and where the strata have been affected by a powerful fault. On the left bank of the Cennen the Upper Silurian Rocks are thrown into a sharp ridge above Golden Grove, the strata containing fossils and dipping 80° E.S.E. (Pl. 34. f. 7.) Thence these beds, still maintaining the top of the ridge and in contact with the Old Red Sandstone, resume their south-westerly strike for a short space, when they are suddenly thrown out to the W.N.W. for a mile (see Map), and then regaining a true south-westerly strike, form the promontory of Nelson's Monument. Between this promontory and Middleton Hall is another transverse fault, in which the junction beds with the Old Red Sandstone have been snapped off and moved considerably to the south-east. This fault has produced only the rudiments, if I may so speak, of a transverse valley[1], for it has caused a slight depression only, in which water runs, although at a height of several hundred feet above the level of the Towy. It therefore differs only from those deeper rents in which rivers flow through ridges, in not having been fissured and channelled to a sufficient depth. It was very interesting to detect in this spot many well characterized fossils of the *Lower* Ludlow Rock, such as *Phragmoceras nautileum, Productus depressus, P. euglyphus, Avicula reticulata,* &c. (Pl. 10, *et seq.*)

Owing to the small development of the Upper Silurian Rocks and their vertical position, the

[1] See similar observations on *rudimentary* transverse valleys in a subsequent account of the Valley of Woolhope.

strata containing these Lower Ludlow fossils are within a field's breadth of the Old Red Sandstone, the intervening distance being apparently occupied by a hardish green or grey sandstone, with few or no fossils, the equivalent of the Upper Ludlow. From Middleton Hall to the Black Pool on the Towy, where the Upper Silurian Rocks pass that river in contact with the Old Red Sandstone, it is still more impracticable to separate this Upper Silurian group into distinct members. Indeed it is even difficult to separate the Upper Silurian Rocks from the Lower; for the hills dwindle away, calcareous matter disappears, and in great measure the fossils; thus in short we appear to lose for a time, the features which characterize those rocks through a range of nearly 100 miles. (Pl. 34. figs. 8 and 9.)

Along this portion of their frontier, the Upper Silurian Rocks in the form of hard quartzose sandstones *lie in disjointed masses, separated by a series of transverse faults, each portion usually ranging from east to west, and dipping to the south, till they approach the Towy, when another snap takes place and the strata have the appearance of being shifted back nearly half a mile, and then projected against the left bank of the river, striking from north-east to south-west.* (See Map.) Here, however, and at Croes ceiliog in the road from Kidwelly to Caermarthen, is a perfectly conformable junction of the base of the Old Red Sandstone and the inferior grey-coloured sandstone, dipping 40° south-east; and again on the right bank of the Towy at Castel-moel is a still clearer and more complete passage from the representative of the Ludlow rock into the overlying Old Red Sandstone. This Ludlow rock is a thick-bedded grey, quartzose, micaceous sandstone, dipping 45° to the south beneath the Old Red, and underlaid by black schists, the mass being apparently void of fossils.

The Towy here escapes through a rent in strata once continuous, but which have been thrown into divergent directions by a fault; so that the case is precisely similar to those of the Severn at Coal Brook Dale, of the Wye near Builth, and of all the intervening streams which escape from north-west to south-east.

Between the rivers Towy and Taaf the Upper Silurian Rocks are still less exhibited, but being connected with a line of trappean rocks they will be again alluded to. At two miles south of St. Clare, on the right bank of the Taaf, we meet with slightly inclined beds of unaltered Upper Silurian Rocks, which, passing into Pembrokeshire, will be best understood by reference to their description in the next chapter, only here remarking that the river Taaf, as well as the Towy, flows in a great transverse dislocation, to which more pointed allusion will be made in describing the Llandeilo formation as it appears at Clog-y-frain, where it enters into Pembrokeshire.

## "*Lower Silurian Rocks.*"

We now return to the north-east of Caermarthenshire to observe the relations of the underlying deposits, and to follow their course to the south-west. The Lower Silurian Rocks of this county are in some places not easily separable from the Upper by mineral characters, particularly in the environs of Llandovery, where undulating hills of sandy and argillaceous schist can be proved to belong to the Caradoc sandstone only by containing at wide intervals casts of the well characterized fossils of that formation[1].

[1] That this range of hills, including the Llandovery building-stone, is in the equivalent of the Caradoc sand-

The hill of Goleugoed has hitherto proved richer in organic remains than any other portion of this tract, but all the strata lying between Llandovery and Llangadock are so disturbed and affected with reversed dips, that it is difficult to separate the younger from the older strata with precision. At Blaen-y-cwm, near Sardis chapel, dark sandy grits are heaved into vertical positions, flanked by schist and dark grey, white-veined quartzose sandstone, striking from south-east to north-west. In these grits were found some fine specimens of *Nautilus undatus*. (Pl. 22. f. 18.) Again, near the summer-house on the point of the hill of Glas-alt-fach is thin-bedded, bluish grey, slightly micaceous sandstone, dipping to the north with a strike from east to west; whilst at the western end of the hill, near the high road, coarse quartzose grits of the same character dip 45° S.S.E. and strike N.N.E. and S.S.W. (See Map.) There is no doubt, however, that these hills belong to the Caradoc sandstone, for they contain many remains peculiar to that formation in the quarries at Rhiw-felig, Llwyn-y-wormwood, Cefn rhyddan, Goleugoed, &c.

Many well known Caradoc fossils are mixed with some other species which I have not observed in Shropshire or Montgomeryshire. Among these fossils, figured in Pl. 19, 20 and 21 are *Orthoceras bisiphonatum***, *Turbo Pryceæ***, *Buccinum angulatum, Turritella cancellata, Terebratula pusilla, T.* 17*-plicata***, *T. tripartita, Pentamerus lævis, P. oblongus, Orthis protensa, O. lata, O. radians, O. aperturata, O. bilobata, Spirifer plicatus, S. liratus, Atrypa crassa, A. acuminata, A. lenticularis, A. globosa, A. plana, A. orbicularis, A. undata, Productus depressus* (var.), *P. sericeus, P. sericeus* (var.), *Orbicula granulata*, &c. (Those marked * have not been found in other localities.)

The Llandovery building-stone has not generally the firmness and durability of the Caradoc sandstone, being so loaded with argillaceous matter that if not speedily used and cemented in a horizontal position, it decomposes like the "greenstone" of the Upper Silurian Rocks of Shropshire, Montgomery, and Radnor. We thus see that the two groups at distant points have completely changed their lithological characters, for, as already remarked, p. 190, 204 *et seq.*, the Upper Silurian Rocks, which in Salop are more or less incoherent mudstones, are here brittle, compact sandstones, whilst the hard Caradoc sandstone of Salop has passed into incoherent schist. But as if to torment the unfortunate observer who would draw inferences from lithological structure, there are still striking exceptions to this rule. We have stated that at the south-western end of these undulating hills (at Glas-alt-fach) the beds become hard, quartzose, and slightly conglomerated, and if we follow them to the north-east, through the

stone has been chiefly established through the zealous cooperation of Mr. Williams, surgeon of Llandovery, and his son Mr. Stewart Williams, who have collected fossils from all the adjoining quarries, wherever a trace of them could be detected. From his acquaintance with the Welsh language, and his intimate knowledge of the topography and history of his native country, Mr. Williams has been enabled to render me most valuable assistance. I have named the prominent fossil shell (found in the tilestone of Cwm-dwr by my able friend) *Turbo Williamsi*, Pl. 3. f. 6, as a slight tribute of respect and regard.

Mwmfre Hills, we find that in the still higher ground around Noeth-grüg (1500 feet above the sea) they recover the true lithological character of the Caradoc sandstone, the strata being loaded with the peculiar organic remains. These hills constitute the most interesting tract in Caermarthenshire, since they exhibit *a passage on the one side into the Upper Silurian Rocks, and on the other into the Upper Cambrian.*

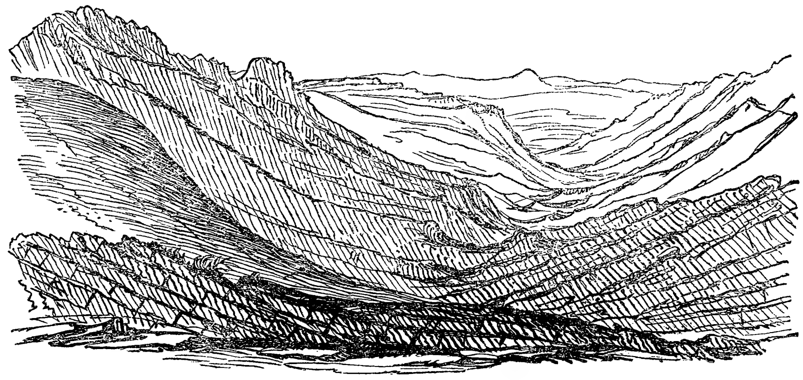
The central part of Noeth-grüg is dome-shaped, with deeply indented steep escarpments on the north-east, and slightly inclined slopes to the south-west, west, and north-west. On the south-east it is flanked by the cliffs of Castell-craig-gwyddon and the low ridge of Gorllwyn, and on the north-west by the sharp ridge of Cefn-y-garreg. The whole mass consists of sandy schist, sandstone, and quartzose grit, with sometimes a fine conglomerate. For the better comprehension of the arrangement of the strata, I refer to the transverse section from the escarpment of the Old Red Sandstone of Mynidd bwlch-y-groes, across the Silurian System, to the hills of Cambrian rock on the north-west. (See Pl. 34. f. 3.) The beds which first rise from beneath the dark schists of the age of the Wenlock shale are grey quartzose grits, in parts a conglomerate, which mount up into the bold cliff of Castell-craig-gwyddon and dip 75° to the south-east. The lower strata are thick-bedded, and were formerly much quarried for building materials, a fact strongly indicative of the absence of good durable stone in this country, seeing that it has been sought in this rugged and inaccessible spot. The thinner and overlying beds are filled with casts of shells, among which are *Pentamerus oblongus, P. lævis, Orthis Actonia,* &c., *Spirifer liratus,* crinoidal stems with granulated surfaces, and several species of coral.

A short anticlinal line ranges from south-west to north-east along the summit of this ridge, as explained at its north-eastern extremity, where subsiding into a low hill, the strata dip both to the south-east and north-west. The quartzose grits are also bent over in the chief hill of Noeth-grüg, where they undulate and dip in fan shapes to the west-south-west, west, and north-west, covering an area of about four square miles. (See Map and Pl. 34. f. 3.) The eastern and north-eastern sides of these hills terminate with a steep escarpment, on the sides of which beds of schist and argillaceous sandstone appear from beneath the harder sandstone.

The north-western face of the Noeth-grüg is marked by a number of hard, rocky, protruding ledges of sandstone, which dip successively 25° and 30° to the north-west. Descending to the westward into the depression between Noeth-grüg and Cefn-y-garreg (Pl. 34. f. 3.), the same strata are curved into small elliptical basins, as represented in the annexed wood-cut,

Cefn-y-garreg. North-western slopes of Noeth-grüg. 66.

N.W. S.E.



one of which occurs on the summit of a low ridge, extending to the north-east from the farm-house of Cwm-clyd. The most nearly perfect of these basins is that at the foot of Cefn-y-garreg, near a spot called Pant-dreinan, where the strata converge to a common centre, presenting the appearance of a large amphitheatre, in which the banks or seats are formed of the successive strata which issue from beneath each other at angles of 25° and 30°. The synclinal axes of these rocky troughs, trend from north-east to south-west, and are therefore parallel to the anticlinal lines of the higher ridges by which they are flanked. In the annexed wood-cut the spectator is looking along the line of strike in one of these synclinal depressions. In the Cefn-y-garreg or north-western boundary of this rugged tract (the ridge seen on the left) the sandstones and grits are again thrown up, first at angles dipping 35° and 40° south-east, and they are flanked by older strata, which dip 70° and 80° north-west. These older, dark-coloured schists with harder beds, occupy the ridge of Cerrig-gwynion, and strike perfectly parallel to that of Cefn-y-garreg, and resuming the true south-easterly dip, underlie all the strata described, and thus graduate upon the north-west into the rocks of the Cambrian System.

In my third and last visit to this wild spot (July 1835,) I detected fossils in the extreme western flanks of these sandstones of Noeth-grüg and Cefn-y-garreg, including a new species of *Lituite, Atrypa undata, A. rudis, Productus sericeus,* the *Orthis Actonia,* and the *O. flabellula,* &c. (See Pl. 22.) Some of these fossils are even found in the vertical strata of Cerrig-gwynion and Cefn-llwydlo, and are specifically identical with well-known shells of the Lower Silurian Rocks; while the beds in which they occur *graduate on one side into the Cambrian rocks, and on the other into Lower Silurian Rocks*. Occupying, therefore, the base of the latter system, these beds must underlie the Llandeilo flags, which are here represented by a thick zone of black flaglike beds, though I could find no traces of the characteristic *trilobites*. Hence we may infer that the species of these animals which existed in such great abundance while the lower portion of the Silurian System was accumulating, lived only in certain localities, of which the north-western slopes of the Corndon, Salop, the flanks of the Berwyns, the district of Radnorshire north of Builth, the vale of the Towy from Llangadock to Llandeilo, the western extremity of Caermarthenshire, and parts of Pembrokeshire, are the best examples.

The principal drainage of the singular tract of Noeth-grüg is effected by the union near Glyn-moch of several streamlets, which there traverse in a deep gorge the ridge of Cefn-y-garreg. On the south-west bank, the beds of quartzose sandstone dip 75° north-west, whilst on the opposite bank they are contorted, and in one part appear to have been altered. I could not detect any protruding trap, though it is probable that such rock may lie at no great depth beneath these highly disturbed and dislocated strata. Owing to the slight covering of soil or turf throughout the greater part of this rocky tract around Noeth-grüg, all the convolutions and disruptions to which the strata have been subjected are very clearly exposed.

The district is, further, of high interest in affording instructive examples of the distinctions between the planes of slaty cleavage and the laminæ of stratification. The former can be well studied upon the north-western ledges of Noeth-grüg, in strongly marked parallel lines, nearly vertical, as represented in the previous wood-cut; and having a north-easterly and south-westerly strike. They appear at first sight to be true lines of stratification. So much indeed do they prevail over other marks of structure, particularly from the projection of the serrated edges of the layers, that it was only when I found these lines cutting through the organic remains, that I was convinced they were the planes of cleavage which had been impressed upon the strata subsequent to their deposition. The parallelism of these lines is strikingly contrasted with the undulating surfaces of the beds in the

singular troughs above described. So various indeed are the positions into which the strata are thrown by these curvatures, that it is remarkable the planes of deposit and those of slaty cleavage should not occasionally coincide; for instances of this coincidence, though never observable in North Wales, will hereafter be shown to occur in Pembrokeshire.

There is no spot, indeed, within the range of the Silurian rocks, in which the distinctions between cleavage joints and bedding (as laid down by Professor Sedgwick,) are better defined than in the rugged tract of Noeth-grüg; and the preceding wood-cut, made from a rough sketch of my own, will enable the reader to form some estimate of the geological interest attached to this scene[1].

The right bank of the Sowdde from Pont-rhydd-sant to Llangadock, offers only low and obscure undulations of schistose beds; but on the left bank a transverse section, parallel to the river proceeding from Blaen-dyffrin-garn to Tan-yr-alt, exposes a full succession of Caradoc sandstone, containing in their upper beds *Productus sericeus*, var., and other Caradoc fossils; and towards their base flagstones with *Asaphus Buchii*, &c. A zone of sandstone, therefore, is here interpolated between the Upper Silurian Rocks and the true Llandeilo flags, commencing on the sides of the low hillock of trap at Blaen-dyffrin-garn, and expanding to the south-west into the arid hill of Carn-goch. The operation by which a great portion of the ridge has been changed from sandstone into granular quartz rock, will presently be spoken of in describing the trap of this spot. The sandstone contains some of the same organic remains as its equivalents in Shropshire, and other parts; and though much disturbed upon the sides of the trap, and in Carn-goch, yet in the hill of Carreg-gwyn-hir, removed from its influence, the strata are regular, and plunge at 60° beneath the Upper Silurian Rocks of the Tri-chrug. (Pl. 34, fig. 6.) From this point the sandstone begins to thin out, and the strike to undergo changes. At Tre-gib the direction is from east and by north to 10° south of west, overlying Llandeilo flags at a high angle. These sandstones traverse the high road from Llandeilo to Swansea, near the bridge Pont-ladies, with a strike from east to west, and a dip of 80° south. They consist of small fragments of grey quartz and decomposing felspar, cemented by a ferrugino-silicious paste, and contain a thin layer of white pipe-clay. Similar sandstones are again found in the lower and western sides of the hill of Golden Grove, highly inclined, dipping under a thin zone of the Upper System, and passing downwards into black trilobite flags. (Pl. 34, fig. 8.)

Though the Silurian System is here so attenuated that it is scarcely practicable to follow with precision any one of the formations individually, yet it is quite clear that these light-coloured sandstones represent and occupy the same position as the Caradoc sandstone of Shropshire. To the south-west of Golden Grove they are obscurely developed; but the hard quartzose sandstone and fine conglomerates of Glas-coed near Llanarthney, and of Capel dewi, may belong to this division, since they lie between the Upper Silurian Rocks and a zone of the Llandeilo flags. The same quartzose beds are again traversed on the sides of a small brook at Nant-y-caws near Pont-pibwr,

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[1] The laminæ of deposit are the undulating lines, the joints are indicated by those lines which are at right angles to the beds, and the cleavage planes are inclined at 70°. (See wood-cut, p. 352.) In many parts of the environs of Llandovery, particularly in those occupied by schists void of fossils, it is almost impracticable to separate the lines of cleavage, joints and bedding, without examining a large area, and by ascending to the tops of the hills, where the most marked character of the rock is generally to be found. Where the slaty cleavage is very pronounced, as at Noeth-grüg, it is of course much easier to determine what is not the laminæ of deposit than in these half amorphous, half *slatified* masses.

on the high road from Caermarthen to Swansea, where pebbles of white quartz of the size of small beans are disseminated in a base of dark grey schist, with some felspar and green earth, the strata being vertical, and their strike from north-east to south-west. It is no easy task to distinguish these sandstones from the overlying and underlying formations in their progress westward from the right bank of the Towy to St. Clears, on account of great denudations, and the apparent absence of fossils and calcareous strata; but before we enter Pembrokeshire, the Llandeilo flags reappearing in great force, are again clearly separated from the Upper Silurian Rocks by thick masses of yellow sandstone, largely quarried at Llandwror, and containing fossils of the true Caradoc formation. (See Map.)

### "*Llandeilo Flags.*"

Llandeilo flags, distinguished by the presence of the *Asaphus Buchii* and *A. tyrannus*, and underlying the great mass of Caradoc sandstone, are exhibited on the left banks of the rivers Sowdde and Towy below Llangadock. They extend thence by Tan-yr-alt, Pen-y-banc and Pompren-arreth, to the low hills of Pentref and Tir-wyn-fach, where they strike across the Towy, occurring in great force at Llandeilo and in Dynevor Park. From Llandeilo to Caermarthen, this formation is seen on the right bank of the river, chiefly in detached and broken masses, near Llangathen and Llanegwad, the only places where I have detected the rock on the left bank being at Golden Grove and at Capel dewi. Beyond the latter point the calcareous matter thins out, and does not reappear till we reach Clog-y-frain, on the borders of Pembrokeshire, though the course of the formation is traceable at intervals by its organic remains, as at Pensarn, &c., near Caermarthen.

By consulting the map, it will be seen that between Llangadock and Caermarthen, a space about fifteen miles in length, and from half a mile to two miles in width, these Llandeilo flags have been singularly thrown about with divergent strikes and reversed dips. At their north-eastern end a transverse section (Pl. 34, fig. 5.) from Tan-yr-alt, to Blaen-dyffrin-garn, passes over the low hills of Pen-coed, Pen-llan, and Tyr-y-garn, exposing beds of black calcareous flagstone, occasionally very pyritous, and more or less charged with trilobites, alternating with thickish bedded strata of grey, quartzose sandstone and dark shelly grits[1]. These flagstones have a prevailing direction to the south-west, and dip in opposite directions, i. e. both north-west and south-east, at high angles. In following the strata to the south-west, they are subjected to several breaks, by one of which they are deflected to the north-north-west, or nearly at right angles to their prevailing strike; but they resume their south-westerly direction, and range with tolerable regularity along the western flanks of Cairn-goch and Carreg-cegin, plunging at one or two spots at high angles beneath the overlying sandstone. (Pl. 34, fig. 6.) At Pompren-arreth, the subordinate beds of grit thinning out, the blackflags and shale

[1] Encrusting springs issue from some of the more calcareous beds.

are exposed in a thickness of nearly half a mile in highly inclined strata, (70° to 80°) on the banks of the brook, extending eastward to the waterfall. Many casts of trilobites occur in these beds, and also bands of stone sufficiently calcareous to be burnt for lime.

The prevailing strike is here 30° south of west, whilst at Pentref and Tyr-wyn-fach, only one mile nearer to Llandeilo, beds charged with the same trilobites, are wrenched from the prevailing strike and range, in vertical positions to the west, and even 10° north of west. If we trace the beds to the westward across the valley of the Towy, we again meet with them greatly developed at Llandeilo, but in the very first ledge on the eastern side of the town they recover their south-westerly strike. This direction is however maintained a very short distance, for in the space occupied by even the high road, the same beds are broken off and trend on one side to the west, dipping 80° to the north, or nearly at *right angles* to the beds observed upon the other. In most of the quarries in and about Llandeilo, the number of dislocations to which the flags have been subjected is truly surprising, the strata being for the most part in vertical or highly inclined positions. (See Map, and Pl. 34. figs. 7 & 8.) In one of the chief quarries of Dynevor Park, the beds are thrown so completely out of the prevailing direction, as to strike E.S.E. and W.N.W., dipping 70° N.N.E., whilst in Bird's Hill they bend round from 15° W. of N. to true *N.W.*, S.E., though in the Llangathen and Grongar Hills, the old strike of N.E., S.W. is resumed. In fact the beauty of Dynevor Park depends upon these dislocations, by which the surface has been diversified and thrown into separate knolls now wooded to their summits. (See wood-cut at the head of this chapter, Dynevor Park in the foreground, Golden Grove in the distance.)

The prevailing flagstone, in beds from two to four inches thick, is dark-grey or indigo colour when extracted, but it weathers to a light ashen hue, the surface being in some parts covered with a profusion of casts of the *Asaphus Buchii,* other organic remains being rare. The calcareous flags are very generally traversed by veins of white calcareous spar, from one-tenth to half an inch wide, which usually divide the beds into rhomboids. These flags occasionally, as at Grüg, about three quarters of a mile north-west of Llandeilo, pass down into thicker masses of sub-crystalline, dark, impure limestone, having an east and west strike, and a dip of 45° to the north. They contain encrinites, a few casts of shells, *Asaphus Buchii* and *A. tyrannus.* The beds have a corrugated surface, due to the mass being composed of small irregular concretions, and this structure is partly occasioned by the unequal dissemination of sand and even of small pebbles in the calcareous matrix. The true flag-like structure of the Llandeilo flags is not discernible in any of these beds. The Grüg quarries exhibit the oldest calcareous beds of this formation, as they lie to the west and north-west of the flags, and the same nodular limestones occur in Llangathen and Grongar Hills in similar positions, rising from beneath the younger strata and graduating on their western flanks into the rotten slates and greywacke grits of the inferior or Cambrian System, in which (in this district) all traces of fossils are lost.

To the south-west and west of Llandeilo the flagstones are found on both banks of the Towy in distorted masses, none of which have a continuous strike for more than a few hundred paces. Below

the house of Golden Grove, the principal strike is west-north-west, the strata being nearly vertical, or dipping 80° under the younger group, but in the great quarry the strike is 29° north of west. These strata belong to the younger portion of the formation, passing upwards into shelly sandstone, containing, besides the *Asaphus Buchii,* the casts of shells generally characteristic of the Lower Silurian Rocks, some of which are figured Pl. 22[1].

Between Golden Grove and the point occupied by these flags on the opposite banks of the Towy, is a distance of two miles, occupied by a flat alluvial plain, which has evidently been the scene of great dislocations and subsequent denudation; for on examining the rocks extending from Llangathen through Grongar Hill, to the old castle of Dryslwyn, (see Map), the strike of the same beds is almost completely reversed from that of Golden Grove. In this ridge, the prevailing south-westerly direction is resumed, subject however to striking aberrations, as near the house of Berlland y wull, where vertical beds of impure calcareous nodules and flag, strike from north to south.

The best examples in Caermarthenshire, where this formation passes into strata of the inferior system, are seen near the hamlet of Rhiw-yr-adar and along the western sides of Llangathen and Grongar Hills. (Pl. 34. f. 8.) Here the flags, highly inclined and contorted, graduate on their north-western face into irregular concretions of impure limestone, occupying the same place as the limestone of Grüg. They first alternate with dark and light grey grits, a coral being sometimes discernible, and are succeeded by beds of schist with soft sandstone and grit, containing casts of encrinites. There is also an imperceptible passage from these sandy beds into still more ancient strata void of fossils; viz. the black schists, which, in common with Professor Sedgwick, I consider the link connecting the Cambrian and Silurian Systems. Similar successions are observable near Llan-rhaidr, in Denbighshire, p. 307, and in Pembrokeshire.

The Llandeilo flagstones appear the last on the right bank of the Towy, in little parallel ridges on both banks of, and near the mouth of the river Cothi; they are also obscurely seen near Llaneg-wad, and in a marked manner at a hamlet called Nant-y-redig. Here the strata striking true north-east and south-west, and dipping 70° *to the south-east,* are composed of dark impure limestone, with some fossils, and are underlaid by less calcareous beds, traversed by numberless veins of pure white calcareous spar, and these again by black flagstones, of two to four inches thick, having a ferruginous weathered exterior. A little to the north-west of these quarries, or at the foot of the hill of Galt-fawr, one of the lowest masses of limestone of this age, containing casts of large trilobites, protrudes above the high road, exhibiting dark sub-crystalline concretions, overlaid on one side by an arched stratum, a few inches thick, of hard, earthy limestone, and on the other by thin beds of shale, and thick beds inclosing small calcareous nodules with corals and other fossils. The calcareous flags of Nant-y-redig may be traced in their strike to the south-west, reappearing at Capel dewi, on

[1] In all the quarries around Llandeilo, and in many other situations both in Caermarthenshire and Pembrokeshire, the *Asaphus Buchii* is not the only large trilobite peculiar to these flags and limestones. That species, so easily distinguished by its round form (see Pl. 23 and 24.), is frequently associated with another, having a caudal extremity more or less pointed, and differing from the *A. Buchii* in the termination of the post-abdominal segments. To this species I have assigned the name of *Asaphus Tyrannus.* See Plate 24, figured from a splendid specimen presented to me by the Earl of Cawdor.

the left bank of the Towy. From this point to the south and west, the formation contains no calcareous masses till we reach Clog-y-frain, on the borders of Pembrokeshire, a distance of about fifteen miles. Its course however is marked on the left bank of the Towy at Pont pibwr, opposite Caermarthen, by trilobites, which occur in nodules in black argillaceous rotten shale, (see Section, Pl. 34. f. 9.) passing down into strata of black schist, containing at Mount Pleasant, casts of several shells, most of which are greatly contorted.

I consider these fossils, like those west of Noeth-grüg, to occupy the base of the Llandeilo formation. Among them are several of new species not mentioned in previous chapters, such as *Nucula lævis*, *Spirifer alatus*, *Euomphalus perturbatus*, and *Ogygia Murchisonæ*[1], Pl. 25. figs. $3^a$ & $3^b$, together with the well-known fossil *Orthis Flabellula*, and others common in the Lower Silurian rocks.

Between the Towy and Taaf, and thence extending by St. Clears, the black shivery schists are supposed to represent the Llandeilo flags, although they contain no calcareous beds; or, as far as I could observe, any very characteristic fossils. But at Clog-y-frain to the west of St. Clears, and on the left bank of the Towy, a prominent ridge of limestone rises from the midst of black schists and flags. In this ridge are three calcareous bands, separated by calcareous flags and shale, making in all a thickness of upwards of 200 feet: the uppermost band of limestone being of very fine quality, and *at least seventy feet thick*, has been the most largely quarried. The beds are, therefore, much thicker than those of any mass of limestone of this age previously noticed. One of these, about ten feet, is in fact a complete aggregate of shells, corals and trilobites, and is of a dark-bluish grey colour, crossed by white veins, which mark the course of the joints. Some of the beds are so charged with crinoidea, that they might be well termed encrinite limestones; and among these remains is one having pentagonal joints. *Orthis flabellula*, *O. alternata*, *O. canalis*, and *O. bilobata* are the prevailing conchifers. Corals are very abundant on the surface of the beds, and *Asaphus Buchii* is not unfrequent. This beautiful marble rock passes up into sandy limestone, and the calcareous matter diminishing, is soon lost amidst the surrounding shale and sandstone, in the form of a concretion.

The variations in the strike and dip of the beds are proofs of the powerful disturbances by which they have been affected. The strata bend round from W.N.W. to E.S.E., to N.W. and S.E., the last strike being absolutely at right angles to the general direction of the formation in South Wales; and the dip, instead of being to the south-west, so as to pass under the superior formations, is completely reversed, or thrown over to the north-east at angles of 55° and 60°. On examining the adjoining gorge of

[1] The principal trilobite figured from this locality is a new species of *Ogygia*, which I have named after Mrs. Murchison, who unexpectedly discovered this fossil in a locality where I had abandoned the hope of finding one. The trilobites and fossils of this spot, together with those of Llandeilo, bear so strong an analogy to those described by M. Brongniart from Angers in France, that I have little doubt of the black flags of the latter place proving to be of the same age as the bottom beds of the Silurian System.

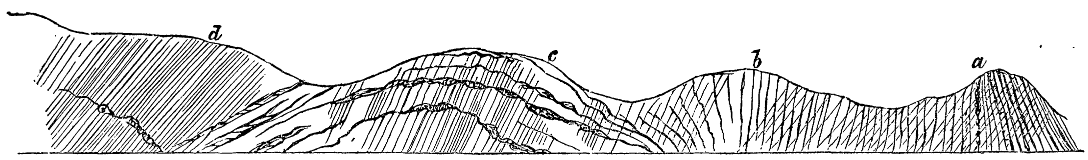
the Taaf, the strata are found to be tilted both to the north-east and to the south-west, in which direction the black flags pass under Caradoc grits and sandstones, which in their turn are overlaid by Upper Silurian rocks, and the Old Red Sandstone of Cyffic. (See Pl. 34. f. 10.) The line of fault by which the Llandeilo flags are affected, is parallel to the river Taaf, and on its left bank. This is the last great flexure and snap to which the formation has been subjected before entering Pembrokeshire; for although the *whole* of the Silurian System has undergone similarly violent convulsions, (see Map), yet as the amount of each dislocation can be marked with the greatest precision by the changed direction of the beds of limestone, attention has been particularly directed to them.

The preceding notices of the dislocations in Caermarthenshire have been fuller than usual, because in this country, the Silurian System, after its long course from north-east to south-west, is met by a succession of powerful cross and compound fractures, which towards Pembrokeshire become so frequent, as to give it for some distance an east and west direction, although, as will be shown hereafter, the south-westerly strike is resumed before the final disappearance of the system in the coast cliffs of that county.

## CAMBRIAN SYSTEM.

### (*Caermarthenshire.*)

67.




*a.* Passage from Lower Silurian to Cambrian. *b.* Dull schists, with imperfect slaty cleavage.
*c & d.* Stratification marked by undulating quartzose beds; the mass traversed by lines of slaty cleavage.

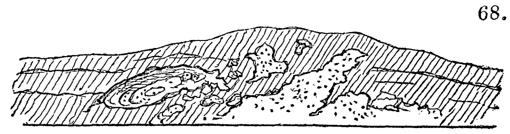
From the hills near Llanwrtyd, whence the view forming the vignette to the last chapter was taken, the rocks of this system range to the south-west through mountainous and sterile tracts, their south-eastern frontier passing near Llandovery to Llangadock; and trending afterwards by the west of Llandeilo to Caermarthen, they are deflected to the west, in common with the Silurian formations. If these rocks have a tolerably well-defined boundary in that part of their eastern frontier where they have been described as passing into the younger deposits, (Noeth-grüg, Llandeilo, and Grongar,) they have no lines of demarcation or division within themselves, and extend over two-thirds of Caermarthenshire, without any material changes in their mineral structure. A detailed examination of this vast area is not within the objects of my work.

Between Llanwrtyd and Llandovery are dark rotten schists, having a dull surface, the whole oc-

casionally affecting a slaty cleavage, and frequently appearing as if dipping to the north-west, when the dip of the beds is to the south-east at 70° or 80°. Good examples of this are observable to the south-east of the Sugar Loaf, near the spot where these lower strata pass into the Silurian System.

The separation of the Lower Silurian rocks from the Upper Cambrian, has been generally effected, by assigning to the former those beds which contain fossils, and to the latter those which do not. For although animal remains occur in the Cambrian strata in many other parts of England and Wales, nature has *here* afforded us no such evidences, since the incoherent schists near the base of the Silurian System, and those which extend over so large a portion of the region of slaty Cambrian rocks, are *lithologically inseparable.* As we ascend in the higher and more arid regions of the north-west, ribs of grit and sandstone begin to alternate with these slaty schists, and finally the beds of schist becoming harder, have glossy laminæ, are penetrated by thin veins of white quartz, and put on more the characters of slate. Still older slaty strata, lying still further to the north-west, contain thick courses and concretions of quartzose grit, and in these the dip is often reversed to the north-west. The fragments of slate included in these coarse grits are sometimes indented by the surfaces of small quartz pebbles[1]. In their range to the west of Llandovery (Pl. 34. fig. 2.), these rocks are here and there diversified by concretionary masses of grit, some of which have been recently exposed, by cutting a new road from Llandovery to Llampeter in the gorge of Cwm-dwr[2], north-west of Llanwrda. In some parts these concretions are perfectly isolated in the slaty mass, in others they run into contorted and imperfectly formed strata, in which obscure lines of bedding are perceptible, dipping to the south-east and north-west, whilst the predominant lines of slaty cleavage are invariably inclined to the north-west, the latter being what most observers would take to be the true lines of stratification. The section (f. 2. Pl. 34.) illustrates these examples, and affords an additional confirmation of the truth of the doctrine of slaty cleavage taught by Professor Sedgwick. (See p. 352.) Either, however, the crystalline slaty impress (as is indeed most probable), has not here been communicated in so decided a manner as in other parts of Wales; or the quartzose masses have been gathered together by concretionary action, subsequent to the operation which produced the slaty structure, for the parallel planes of the slaty beds often terminate abruptly against the edges of the concretions[3]. The schistose beds at their points of contact with these concretions are more sandy and micaceous than usual, with ferruginous discolorations proceeding from the decomposition of iron pyrites. This ingredient (the curse of most countries where

68.

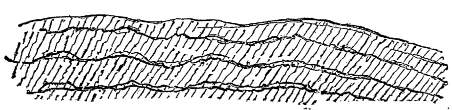


[1] It is from the summit of one of these wild mountains, Esgair davydd, that the large sketch, facing p. 346, was drawn, combining, in one view, all the formations from the Old Red Sandstone to the greywacke slates inclusive.

[2] A different *Cwm-dwr* from that in which the Upper Silurian rocks are so well developed.

[3] This phænomenon is precisely in accordance with what I have recently observed in parts of the slaty schistose system of Ilfracombe in North Devon, when in company with Professor Sedgwick. There the beds of sandstone predominate; and the slaty cleavage, after passing through the schist, stops suddenly at the bed of sandstone, thus:

69.



it abounds)[1], is the only simple mineral to be found throughout large tracts of these slates, the occurrence of ores of real value, such as at Nant-y-moen, being a very rare phænomenon in Caermarthenshire. In the higher parts of the range called Llansadarn mountain and Carreg-fawr, there are strong sandstone and grits passing into quartzose conglomerates, similar to those in the gorges of the Elan and Wye near Rhayder. If we attempt to follow any one of these bands of grit or conglomerate to the south-east or north-west, all traces of it are soon lost, the prevailing rotten slate rising to the surface; but pursuing the direction of the strata, we again meet with similar quartzose masses, such for example are the rocks of Taliaris warren, distant five or six miles from those of Llanwrda and Llansadarn. These quartzose grits and conglomerates are therefore only irregular aggregates or large concretions, where the amount of coarse materials was not sufficient to form continuous strata. As the schistose beds are generally fragile, rarely affording slates worth extracting, and as there is not a trace of limestone in the region, these coarse sandstones are the only useful rocks of this part of Caermarthenshire; and hence they are extracted both for the roads and rough masonry.

In the neighbourhood of Caermarthen, hard grits of this class are quarried at Galli-cistaniog on the left bank, and near Abergwylli on the right bank of the Towy. I have before remarked that in the neighbourhood of Caermarthen the Silurian System dwindles to a narrow obscure zone, which is strikingly proved by the proximity of the edge of these slaty greywacke rocks to the Old Red Sandstone. (See Map.) I examined these Cambrian rocks towards the interior by traverses from Llandovery to Llampeter, and from St. Clears to Newcastle Emlyn; but in no portion of the wide space between these places have I detected any striking variety of mineral structure; the whole tract being occupied by schists, grits and sandstones, more or less impressed with a slaty cleavage, ranging generally from north-east to south-west, and dipping to the *north-west*. This cleavage is rarely perfect, though slates are sometimes worked. Between Llampeter and Newcastle Emlyn the strata occasionally change their prevalent direction from E.N.E. to W.S.W. to east and west. Between Caermarthen and Mydrim are similar oscillations from a south-westerly to a true westerly strike; but in the transverse section from St. Clears to Newcastle, on the right bank of the Afon-gynin, there is no deviation from the westerly strike with which the rocks of this age, in common with those of the Silurian System, are thence prolonged into Pembrokeshire. (See Map.) This slaty system of Caermarthenshire (we may say the same of the adjoining county of Cardigan) contains very little calcareous matter. The only exceptions occur at intervals in a slaty zone, not far removed from the frontier of Silurian rocks. At Mydrim, four miles north of St. Clears, hard dark-grey, thick flags, slightly calcareous, pass into imperfect concretions of a very impure limestone, underlaid by schists and quartzose grits. In this calcareous mass I could detect no fossils, but the geodes contain crystals of quartz, and the beds are traversed by veins of the same. It will be observed, by consulting the map, that these strata strike a little to the *north* of west and dip northwards 45°. Similar calcareous flagstones, quarried for roofing slates, and of about the same age as those at Mydrim, occur at Pont-y-glaen and north-west of Abergwylli near Caermarthen, but they are apparently equally void of organic remains. These beds dip 35° north,

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[1] I would partially except from this character those tracts where iron pyrites, by its decomposition, produces medicinal springs, (see pp. 34, 155, &c.), as well as those districts where the pyritous clays and marls have been used for the manufacture of alum; but pyritous clays, as far as I have observed, are invariably of slight agricultural value.

and are traversed by lines of slaty cleavage also dipping northwards, but at an angle of 45°. In some parts of the quarry, indeed, the surface of the beds and the planes of slaty cleavage *almost coincide*. Great perpendicular joints cross these slates from north to south, and there are also many backs or joints coinciding with the strike, thus indicating both dip and strike joints. These two sets of joints and the planes of cleavage give rise to rectangular prisms terminated by oblique planes. Veins of calcareous spar mark the course of many of the joints, and one calcareous band of about half a foot in thickness is parallel to the beds.

We cannot take leave of the slaty rocks of Caermarthenshire without reminding the reader, that although some of them in this district may be the equivalents of the Longmynd, or mineral axis of Salop, they are here separated from the Silurian System by perishable schists, with beds of calcareous slate, grit, and sandstone occasionally containing fossils. This intermediate member of the series, though made up of the same ingredients as the slates, is seldom affected by a complete slaty cleavage. It is further worthy of remark, that the very few fossils which occur in the intermediate zone are never detected in the fine shale, though we might suppose its structure to have been favourable to the conservation of organic remains. The beds containing fossils are those hard grits or sandstones which reappear at wide intervals in the schist. In short, the zone intermediate between the Lower Silurian Rocks and the slates, is scarcely to be distinguished in external appearance from many of the districts in which the incoherent beds of the Silurian rocks are most developed. The strata in both cases decompose to mud; but in agricultural value the beds of the Silurian System have a manifest superiority, containing usually calcareous matter, whilst its prevalent absence in the upper part of the Cambrian System renders the soil comparatively cold and sterile. The perishable nature of the schist ("rotch") throughout such large tracts, and the absence of bands of hard sandstone by which it might have been sustained, have led to their extensive denudation, and has necessarily obscured in most places the passage from the Silurian into the Cambrian System.

Of the slaty impress, much has been said to confirm the view of Professor Sedgwick that it has been superinduced upon the materials of which the strata are composed, long after their accumulation. We further learn from observation in Caermarthenshire, that this impress has been strongly communicated in some parts, and suddenly cut off or omitted in others; and lastly, we perceive, that as it has been repeated at distant parts in rocks of *different* ages, it is no test of the antiquity of the rock affected, though it may be inferred, that the older slates having undergone a greater number of metamorphoses, may thus (*cæteris paribus*) have been rendered more crystalline than the younger. Let us hope that the day is not distant, when the experimental chemist, whether employing heat, electricity, or both these great causes of change, shall reveal to us the method by which the fine silt from which these schistose masses were derived, was converted into the slaty form; till then, we fear that field geologists must remain satisfied with establishing the actual condition of the subject.

### *Organic Remains in the Cambrian Rocks of Caermarthenshire.*

Besides the crinoidea, and a few traces of shells detected in the beds of passage between the Llandeilo flags and the Cambrian rocks, singular forms have been recently discovered near Llampeter, in the faces of the building-stone of that place.

This discovery was made by the Rev. A. Ollivant, Professor of Llampeter College, and the specimens procured by him are delineated. (See Pl. 30.) These convoluted forms seemed at first sight to represent zoophytes, but after a long examination, no zoologist has ventured to pronounce that they ever belonged to the animal kingdom. Neither has the botanist been willing to recognise them as vegetables, although in common with the zoologist, he allows that they have a regularity of form which indicates organic structure.

### *Trap and Altered Rocks in Caermarthenshire.*

When I commenced the examination of South Wales, I was, like other geologists, unacquainted with any trap rocks in Caermarthenshire; nor did I discover any trace of them till the summer of 1833. The spot at which they were first seen is in the rocky knoll of Blaen-dyffrin-garn, on the left bank of the Sowdde, about three miles south-east of Llangadock, and about one and a half mile north-west of Pont-ar-lleche, where the Old Red Sandstone and the Silurian rocks are conterminous. Seeing the great extent to which all the formations of this neighbourhood had been dislocated, I was anxious to discover any rock of intrusive character which might explain such operations, yet this knoll was for some time the only one I could detect.

This trap is more or less porphyritic, having a base of compact felspar partly concretionary, and sometimes beautifully mottled by green earth. It occasionally contains a little lime. The structure is both amorphous and flaglike. These varieties protrude at various points along the summit and upper sides of the hill. A black flagstone and shale, which dip from its south-eastern face, are not seen in contact with the trap, but at the distance of more than one hundred paces, and near the base they are thrown off at an angle of 30° to the south-east, and in a state of hard, black, slightly calcareous flag, which has been quarried, and in which was found the beautiful small trilobite called *Trinucleus Lloydii*, (Pl. 23. f. 4.) On its western, north-western, and south-western faces, this little ridge tilts off sandstone, which has been shown to form a part of the Caradoc formation. It is most instructive to observe how precisely similar is the effect of this contact, to that described in the Wrekin, the Caradoc, &c., where trap has thrown up sandstone of the same age. Near the north-western face of the knoll, the sandstone resting on the trap is a complete quartz rock of conchoidal fracture, the grains of sand exhibiting all the appearance of having been agglutinated into a hard, homogeneous mass. On the side above the farm-house of Prenteg, this altered rock presents a bold and rugged vertical face, of about sixty feet in height, in which there are slight traces of bedding, the whole resembling a confused assemblage of huge trapezoidal blocks, above which the quartz rock assumes a stratified structure, and about thirty paces distant from the nearest boss of

trap, dips towards the hill or to the south-east. In other spots upon the sides of this little hill, I collected some very slightly altered sandstone, charged with fossils which characterize the beds of the same age in Shropshire. By continuing a transverse section from the centre of the hill to the north-west, a small valley is passed, beyond which the sandstone and grit resume their ordinary characters, the beds dipping to the north-west, or from the eruptive trap[1]. I could discover no traces of the prolongation of this trappean axis in its strike to north-east, for the beds of shale and flag fold round it, and in the beds of the Sowdde at Rhydd-y-sant are little disturbed. But to the south-west the line of altered rocks is most strikingly marked for several miles. Gnarled and broken bosses of quartzose sandstone, passing into quartz rock, occupy the wooded hills of Pentre-bach, whence they rise by Carreg-alt to the hill of Cairn-goch, 700 feet above the sea. This hill, so very remarkable from the natural strength of its position, stands out between the rectilinear and mural ridge of the Trüchrüg before described, and the valley of the Towy. Hence, doubtless, it was selected by the Romans as an encampment[2].

We thus observe, that the phænomenon of altered rocks is just as strikingly displayed in this corner of Caermarthenshire, where trap protrudes, as in the north-east of Shropshire, distant nearly one hundred miles, and therefore we are completely borne out in referring these effects to igneous action; the same causes and the same effects being invariably associated.

It may be asked, whether the analogy is further proved in Caermarthenshire by the exhibition of metallic veins. Now it has been shown, that wherever trap rocks protrude, in the counties of Salop, Montgomery, Radnor, or Brecknock, the strata in contact are more or less veined, and although these veins do not always contain valuable ore, the point (as respects theory) appears to be quite as conclusively established by the existence of poor veins, containing merely crystallized pyrites, lime, barytes, &c., as if such veins were loaded with the richest metals. The truth of this assertion has been very clearly proved in the Corndon and Shelve district in Shropshire. It is doubtless dangerous to assert, that *all* mineral veins are connected with igneous operations, but as wherever trap rocks intrude, the hardened and indurated strata are more or less intersected by veins, we are led to conclude that such veins are as much the result of the intrusion of the volcanic

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[1] From specimens collected by the Rev. Henry Lloyd, of Tan-yr-allt, two other thin bands of porphyritic and slaty trap have pierced through the strata, the one ranging from Gorrllum by Carreg-folgam, the other by Hendre-felin, between Pont-meredith and Tal-y-garn; the protuberances of quartz grit along their lines favour the supposition. I am also indebted to Mr. Henry Lloyd for pointing out to me the position of an ancient Crom-llech, called Llech-filart, which stood in the low grounds to the north of Blaen-dyffrin-garn, but which was barbarously destroyed a few years ago by an ignorant tenant. According to the tradition of the country, this was the last place in Britain where human sacrifices were offered, and in more recent times, feuds were reconciled and good fellowship re-established by shaking hands over this stone. In an excavation, Mr. H. Lloyd found bones beneath this Crom-llech, which proved to be human. This is one of the many spots in South Wales and the adjoining English counties which have great antiquarian interest attached to them.

[2] The form of the encampment is a parallelogram, the larger diameter of which corresponds with the axis of the ridge, and is therefore in line with the main direction of all the deposits in this region. Four entrances are still discernible: a slight depression in the centre must have added much to the security of the camp. The north-western, or one of the largest faces, is a natural defence of quartz rock *in situ*, the beds of which dipping to the north-west, present a bold precipitous face to the valley of the Towy. The other walls, which in places are still twenty to thirty feet high, have been formed by piling large and shattered blocks, which, from their angularity, give a cyclopean character to these venerable and desolate ruins.

matter, as the induration and alteration of the beds; for even this zone of Caermarthenshire trap is not without its metalliferous combinations, although they are of small extent. In the younger strata of the Silurian rocks, which are parallel to the ridge of Blaen-dyffrin-garn, and Cairn-goch, veins of lead have been partially worked, passing through the vertical strata on the banks of the Sowdde, and similar veins have been more extensively cut into in the prolongation of these altered strata near Pen-cae-sarah, and in the adjacent deep dingle, small filaments of copper ore have also been discovered along the flanks of the quartz rock of Cairn-goch, precisely analogous to those on the sides of Caer Caradoc.

### *Trap of Castel cogan, &c.*

A much more extensive outburst of trap than that of Blaen dyffrin-garn, occurs between the rivers Towy and Taaf, in the south-western district of Caermarthenshire. This trap has also been erupted on a north-east and south-westerly fissure, and is traceable at intervals for three to four miles, from a spot called the Glog, by Capel and Llangynog, to Castel cogan and Gallt-y-minde, where it terminates in rugged hills on the left bank of the Taaf. At Gallt-y-minde the rock is a hard, dark-grey, cream-coloured or pink, compact felspar, projecting in irregular and angular masses, with veins containing crystals of quartz, and minute crystals of iron pyrites. Thence it rises into the highest ground in this tract, surmounted by the remains of the ancient camp of Castel cogan[1]; the rampart of which has been entirely constructed of this rock.

The line of eruption towards Llangynog is marked by masses of amygdaloid, protruding through contorted schist and grit. From this point the trap subsides for some distance, but it reappears at Capel in the form of a concretionary felspar rock, in parts having a brecciated aspect, and passing into an imperfect greenstone. The line of outburst is also flanked by masses of volcanic grit, passing into a felspar conglomerate. At the Glog, where it has been deeply cut into for a road-stone, the base of the quarries exposes a very hard rock, full of oblique rents and cracks, made up essentially of compact felspar, for the most part concretionary, whilst in the upper part, small pebbles of quartz become apparent, and are frequent near the summit. This felspar conglomerate, with quartz pebbles of the size of eggs, varies from that state to a grit, and when deeply laid open, consists of a concretionary and solid mass of felspar. It occupies several eminences of 500 to 600 feet in height, along the northern face of the line of eruption. (Pen moelfre, &c.) Like the volcanic conglomerates described in Radnorshire and elsewhere, the mass becomes bedded where the quartz pebbles predominate, and therefore constitutes one of those rocks formed by the mixed agency of fire and water.

The discovery of this volcanized tract upon a line of fissure, parallel to the direction of the Silurian rocks, and running so near their junction with the Old Red Sandstone, satisfactorily explains many singular lithological appearances and fractures in the Upper Silurian group, which previously surprised me. It has already been shown, that at several points on the left bank of the Towy, quartzose grits, containing much felspar, and altogether differing from the regular measures of the

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[1] The camp of Castel cogan is probably a Roman work, though the parallellogram is not of the regularity observable in Cairn-goch.

Silurian System, are developed to some extent. Now these contiguous rocks lie precisely between the points of eruption of Blaen dyffrin and Castel cogan, and range in lines parallel to the fissures of eruption.

We thus obtain additional proof that the violent dislocations of the Silurian System, and the lower strata of the Old Red Sandstone of Caermarthenshire, are connected with these linear eruptions of trap, which here, as in Salop, Montgomery, Radnor and Brecon, have determined the chief direction of the sedimentary masses through which they penetrate.

The strata along the line of eruption near Castel cogan, are extensively fractured, and the associated beds of the Silurian System (hard quartzose grits), are in some places not only vertical but actually reversed, as in cases formerly pointed out, dipping 70° to the north-west, and covered by the Old Red Sandstone, dipping 30° to 40° south. (See Pl. 34. f. 11.)

## *Mines.*

The chief mining district in Caermarthenshire called Nant-y-moen, the property of Earl Cawdor, is about seven miles north of Llandovery. It not being my intention to give the details of this valuable mine, I will merely consider its chief relations to the rocks in which it is situated. The strata between Llandovery and Nant-y-Moen belong to the Cambrian System, and consist of dark, thinly foliated shale, enclosing, though very rarely, concretions of quartzose conglomerate, the true "greywacke" of the German miner. Rising abruptly in the midst of this shale is a mural ridge of unbedded, and apparently in parts brecciated, grey quartz rock, penetrated by many veins of white pure quartz. This ridge, called Cerrig mwyn, strikes from north-east to south-west, and is therefore parallel to the leading direction of all the stratified deposits of this region. On the immediate flanks of Cerrig mwyn, the shale is much indurated, and associated with black and white grits, the whole of which are highly veined, whilst in receding on each flank from the ridge, the black shale resumes its regular appearance.

All the mining ground now in use is situated in the north-western flank of this wall of quartz rock. It is, therefore, very analogous to the Stiper Stones, p. 268.

When we consider how many ridges of eruptive trap have been pointed out, ranging precisely in this direction, and that they have often been accompanied by such quartz rock, it is no strained hypothesis to suppose, that Cerrig mwyn is also an altered rock, the trap which produced the change being at no great depth beneath the surface. For without quitting Caermarthenshire, the description already given of the quartz rock of Cairn-goch, as resulting from the eruption of the trap of Blaen dyffrin-garn, goes far to explain the phænomena, for there the trap is only just discernible in a small obscure boss, while the mass of altered rock forms a conspicuous overlying ridge.

There are three principal veins called the master, the red, and the comet. The two first range more or less from north-east to south-west, parallel to the wall of quartz grit, and in this respect they differ from most of the veins around the Salopian trap rocks. The third crosses obliquely, and intersects the red vein. The master vein has been worked only at a high level, near the edge of the protruding wall of quartz rock which flanks it. The other veins are wrought by lower levels driven into the hill which slopes to a small brook, and none of these have yet reached within fifteen fathoms, horizontally, of the edge of the parallel of Cerrig-mwyn. In the master vein, numerous strings of

galena diverge from the chief mass, to the sides of the rider quartz rock; and a rich bunch of ore was worked out on its opposite or south-eastern face.

The red vein is further removed from the rider rock, and has its name from the lead being coated with the hydrate of iron. At the spot where this vein was cut by the comet vein, the ore thickened for a short distance to six feet, much exceeding the average width of this and the other veins. Besides these principal veins there are several cross lodes.

In one part of the works the ore is found in apparently regular beds, forming thin laminæ in a true greywacke grit, composed of small pebbles of quartz and felspar, with a base of black slate. These beds, some of which are metalliferous and others not, have an united thickness of forty to fifty feet, and dip away from the rider rock or the north-west, at an angle of about 25°. Their position is between the red and the comet veins[1].

The levels enter the hill about 500 feet above the adjoining valley of the Towy, and the most extensive are from 1000 to 1200 feet in length. These works are effectually drained by an adit, whose mouth is a little above the rivulet at the base of the hill; and from which is a constant flow of ferruginous water.

Here, as in the country of Shelve, are remains considered to have been Roman mines, which, having been placed upon the steepest side of the hill, and where the ore probably cropped out, were, it is conceived, worked by water? (See further observations below, on the Roman mines of Gogo-fau.)

It is quite evident that mines, situated like those of Nant-y-moen, where vertical shafts or steam-engines are not required, the whole being drained by an adit, must always be of high value, and accordingly I found the works in full activity in 1833, a period when, from the low price of lead, so many mines had necessarily been abandoned.

The ore of Nant-y-moen is for the most part of excellent quality, the varieties called "potter's ore" and "steel ore" being abundant, as well as "small ore," a mixture of the two former.

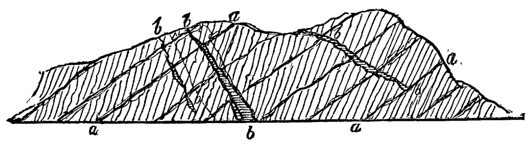
### *Roman Mines of Gogo-fau.*

About ten miles west of Llandovery, on the right of the road to Llampeter, occurs one of those elliptical, quartzose masses, so frequent in the "Cambrian System," of nearly half a mile in length, trending from north-east to south-west like all the associated strata. It is called Gogo-fau, or "*the Caves*," the hill being perforated in many directions by horizontal galleries, considered to have been the work of the Romans. That these galleries were mines, there can be no doubt, since they follow precisely the course of the veins. That they were the work of the Romans is certain; for they have not been used during the period of modern history, and the galleries are much too long, wide, high and deep, to have been the work of the ancient Britons. This opinion has been recently confirmed by Mr. Jones of Dolecothi, who has discovered the remains of baths, medals, gold ornaments, implements, inscriptions, Roman tiles, &c., thus

[1] This is one of the few examples in England of mineral veins putting on a stratified character, by running *for a certain distance* parallel to the true beds of the matrix. Similar veins are seen on a great scale in the lead mines of Bleiberg in Carinthia.

proving that there was a considerable Roman station at the western foot of this hill[1]. The antiquary may decipher these inscriptions, and attempt to inform us which of the Caii left his patronymic to the adjacent village of Cynfil "*Cayo*," whilst the geologist and miner are left to speculate on the probable cause, which led these adventurous and indefatigable conquerors to perforate hills with magnificent galleries, some of which are eight feet high.

The rock of Gogo-fau is a quartzose grit and sandstone, with very slight appearances of slaty cleavage, and in parts exhibiting the rippled surfaces of bedding. The strike is from north-east to south-west, and the beds dip for the most part to the north-west, as seen in the chief building stone quarries of Clochty. Numerous veins of white crystallized quartz, containing abundantly crystallized iron pyrites, traverse the beds both at right angles and obliquely to the strike, as represented in this wood-cut.




70.

*a, a.* Laminæ of deposit. *b, b.* Quartz veins. The highly inclined lines mark the planes of slaty cleavage.

The largest of these veins have been followed, in some instances, to their termination. To these galleries the Welsh assign various names, such as Ogor-hwch, or the Hog's cave; Ogof-fawr, (large cave); Gogor-gowge, &c. The great extent of these excavations is attested by the enormous mounds of white quartz or vein stone debris.

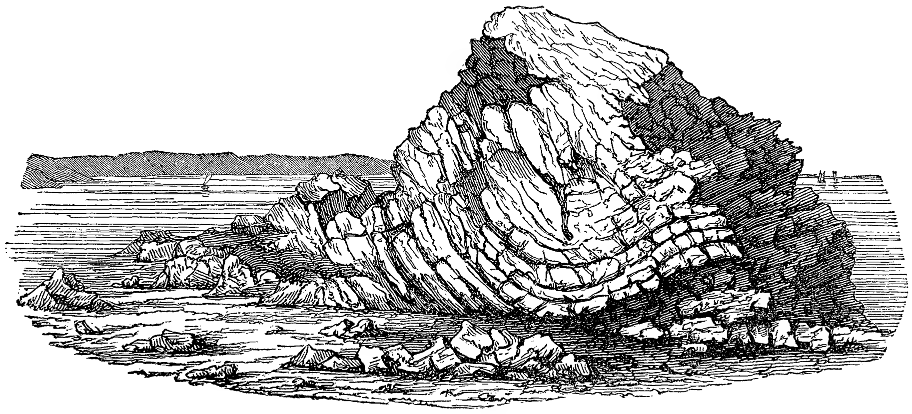
For what purpose these mines were wrought by so sagacious a people as the Romans remains an unsolved problem. As no particles of lead or copper ore can be detected in the mounds of refuse, and as the pyrites seemed to have been occasionally separated from the quartz, it occurred to me that if in any degree auriferous, it might have been quarried for the gold which it contained. On subjecting, however, some of this pyrites to the examination of that excellent chemist, my lamented friend Dr. Turner, he was not able to detect any trace of gold worthy of notice. Whatever the object may have been, the number and extent of the galleries prove that it was pursued with perseverance, and for a length of time. It is probable that the process of grinding the rock was resorted to, for close to the piles of white quartz which have been deposited near the mouths of the galleries, is a large hard block of stone, having on one of its faces, five circular cavities of different sizes, which may have been used for pounding or grinding the mineral

[1] The Earl of Cawdor first called my attention to this curious spot, to which I was conducted by Mr. Williams, of Llandovery. All the objects of antiquity found in the ruins of the ancient Roman baths, were submitted to my inspection by the proprietor, Mr. Jones, of Dolecothi. Mr. Hawkins of the British Museum, having inspected the drawings which I brought away, informs me that one impression of a signet ring represents a fawn holding a bunch of grapes, and the *pedum* or pastoral staff; and at his feet the bacchanalian leopard. The other remains are chiefly red Roman earthen ware, bearing embossed patterns of foliage, animals, &c., with the names of the makers frequently impressed upon the centres of the different vessels.

matter[1]. Moreover, there are distinct traces of an aqueduct by which the waters of the Cothi were so conducted along its left bank from the higher grounds, as to pass near the upper part of these mines, thus leading to the inference, that water works were in use.

While I regret my inability to solve the *mineral* problem satisfactorily, I would call the attention of antiquaries to these and other works of art in Siluria and Wales, which will amply repay them if explored with zeal.

[1] The tradition of this neighbourhood is, that the adjacent church of the five saints, (Llan-pümp-sant) took its name from this stone with the five depressions, and the following is the legend. Five saints travelling in these parts were overtaken by a violent hail storm, when they placed their faces upon this stone, and were miraculously saved, though the force of the storm was such that their heads were indented upon the hard rock, leaving the cavities above described; whilst still further to mark the extent of supernatural agency, the hail-stones have remained for ever as mounds of broken quartz rock. As these quartz heaps must have been in existence, and their origin even veiled in obscurity before such a fable could be propagated, this monkish device of the dark ages proves, that the mines must have been wrought anterior to the introduction of Christianity into this region, and favours therefore the belief, that the Romans were the real miners.



*Stackpole Rock, from a drawing by Mrs. Murchison.*

# CHAPTER XXIX.

## GEOLOGICAL STRUCTURE OF PEMBROKESHIRE.

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Part I. *Introduction.—Coal or Culm Measures.—Millstone Grit.—Carboniferous Limestone.—Old Red Sandstone.* (Pl. 35. figs. 1, 2, 3, 4, 5, 6, 7, 8 and 9.)

HAVING traced the Silurian Rocks to the western borders of Caermarthenshire, I propose to show the manner in which they are prolonged to the coast cliffs of Pembrokeshire. In the mean time, however, as this county contains all the formations from the coal measures to the Cambrian Rocks inclusive, the present chapter is offered as a synopsis of much that has been diffused through the previous pages, concerning some of the overlying deposits, (p. 79 to 174).

Unlike the greater portion of the region examined, Pembrokeshire has received some attention from geologists. The mineralogy of a part of the northern district was described by Dr. Kidd[1], and the geological structure of the southern was laid down, in the year 1820, upon the Ordnance Map by Mr. De la Beche, and published with a memoir in the Geological Transactions[2]. Although the general relations of the carboniferous system (with one exception) were then pointed out, no attempt was made to establish a succession of strata below the Old Red Sandstone. The whole northern district was marked as "grauwacke," a name which, until recently, comprehended every rock from the roofing slates to the beds immediately beneath the Old Red Sandstone; and

[1] Geol. Trans., vol. ii. p. 79. (Old Series.)  [2] Geol. Trans., vol. ii. p. 1. (New Series.)

a stronger proof cannot be given of the imperfect state of our knowledge of these lower rocks, than the mere inspection of a map, beautifully diversified in other parts, yet including under one colour, all those formations with subordinate limestones which constitute the Silurian System, as well as a large portion of the rocks of the Cambrian System. It may indeed be said, that "grauwacke" was at that time considered the limit, on reaching which all stratigraphical and geological definition ceased[1]. It has already been amply shown that this word should cease to be used in *geological* nomenclature, and I shall in the following pages give further proofs that it is *mineralogically* valueless, because rocks undistinguishable from the so-called greywacke (Silurian and Cambrian) of this and other districts, occur both in the Old Red Sandstone and in the Coal Measures.

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Pembrokeshire, the extreme promontory of South Wales, washed on two sides by the sea, and fissured on its southern face by the deep bay of Milford Haven and its accessary inlets, affords extraordinary facilities for the study of its mineral structure. If divided by a line running from east to west along the centre of the county, we find the stratified rocks to the north of that line composed of slates, grit and shales, forming a large portion of the Cambrian System; whilst to the south the older rocks are surmounted by the Silurian System, the Old Red Sandstone, the carboniferous limestone and coal measures. The county is further diversified by a vast number of outbursts of trappean rocks which have exceedingly modified the surface and altered the structure of the sedimentary deposits. An inspection of the transverse section from Fishguard on the north, to Pennyholt Stack on the south, explains their general relations. (Pl. 35. f. 1.)

### *Coal or Culm Measures.*

The youngest sedimentary deposits of Pembroke consist of shale and sandstone, which overlie the millstone grit and carboniferous or mountain limestone, and contain beds of stone coal or culm.

Before, however, we enter on the details required to explain the structure of the culm measures, it may be well to state that there is no *geological* difference between *stone coal* or *culm*, and *bituminous* or *common coal*. They are in fact mere mineral varieties of the same substance, which occur in *formations accumulated at the same period*. The coal, indeed, of the greater part of the South Welsh basin is stone coal, anthracite or culm, and yet there is no field in the world where the age of the deposit is more clearly marked by natural sections.

In casting a glance over the map it will be perceived, that these carboniferous or

[1] Whatever changes may have been effected in the accompanying, in comparison with pre-existing geological maps of Pembrokeshire, I must at once acknowledge the great aid I derived from being in possession of the previous labours of Mr. Greenough and Mr. De la Beche, whose maps in fact are able outlines, which I have endeavoured to work up to the existing state of knowledge.

culmiferous strata of Pembrokeshire are simply a prolongation of the southern limb of the great South Welsh coal-field, which, extending from east to west, bisects the county. Occupying at their eastern extremity the whole of Caermarthen Bay, they appear in nearly an equal extent of coast cliff in St. Bride's Bay on the western, whilst to the south of Haverfordwest, they are spread over a width of about three miles only. In this range they are divided naturally into two parts by the north and south forks of the great estuary of Milford Haven. To the east of the estuary, the coal strata are regularly supported by girdles of millstone grit and carboniferous limestone, but to the west the limestone rapidly thins out, being visible only for a short distance in broken and disjointed patches.

To obtain, therefore, a clear idea of the succession of strata in descending order, the observer must examine the eastern or more regular tract, for example, at Amroth, to the east of Tenby, where the youngest formations are exposed in the cliffs, and proceeding northwards he will successively pass over, 1. Beds of shale and sandstone with culm. 2. Hard sandstone and grit unproductive of culm, a prolongation of the millstone grit of Caermarthenshire. 3. Carboniferous or mountain limestone. 4. Old Red Sandstone. 5. Silurian Rocks. 6. Cambrian Rocks. (See Pl. 35. f. 4. and woodcut, No. 72, p. 375.) All these masses rise from beneath each other in regular succession, and thus confirm the order which has been established by so many natural sections in other parts of England and Wales.

## *Eastern Culm Tract.*

*Culm at Landshipping.*—In no place in Pembrokeshire are the culm-bearing strata arranged with greater regularity than at Landshipping, on the east bank of the Cleddau, where they repose upon unproductive shale and flagstone, which in descending order becomes gradually unproductive of culm, the whole passing down into sandstone representing the millstone grit. This succession is seen upon both banks of the river between Landshipping and Slebech, the transition from the lowest and poorest culm seams to the hard flaglike beds without culm, being particularly well exposed on the right bank, in the beautiful grounds of Picton Castle[1], the strata dipping at slight angles to the south. (Pl. 35. f. 3.) The overlying measures at Landshipping are very productive, and have long been worked by regular shafts. The following is the descending order:

*Section of the Coal works at Landshipping.*

| | Fath. | yds. | ft. | in. |
|---|---|---|---|---|
| Measures (shale, sandstone, &c.) | 10 | 0 | 0 | 0 |
| 1. *Culm or tumbling vein* | 0 | 1 | 0 | 0 |
| Measures | 7 | 0 | 0 | 0 |
| 2. *Culm or rock vein* | 0 | 1 | 0 | 0 |
| Measures | 5 | 0 | 0 | 0 |
| 3. *Culm or slate vein* | 0 | 0 | 2 | 0 |
| Measures (hard sandstone and shale) | 12 | 0 | 0 | 0 |
| 4. *Culm or flint vein* | 0 | 2 | 1 | 0 |
| Measures | 0 | 5 | 0 | 0 |
| 5. *Lower slate vein* | 0 | 0 | 2 | 0 |
| Measures (chiefly sandstone) | 5 | 0 | 0 | 0 |
| 6. *Culm or north vein* | 0 | 0 | 1 | 4 |
| Measures (black rock and shale) | | | | |
| | 44 | 1 | 0 | 1 |

Dip 2 feet in 6, northerly.

[1] The property of Sir Thomas Phillips, Bart., M.P.

The culm in this pit is much broken, and the surfaces of the fissures are frequently coated with mineral charcoal, but in other parts it presents its ordinary pure, clean, and polished fracture. It is much used by maltsters. Plants common in other coal-fields occur not only in the shale but may be detected in the culm itself.

Even in this comparatively regular portion of the field, faults are very numerous, some affecting the strata to the extent of fifteen fathoms, and they are all upcasts to the north. (For the general relations of these coal beds to the associated strata see Pl. 35. f. 4.)

In the Fraisthorpe Colliery, on the west or opposite bank of the river, four beds only of coal have been found, though the shafts are deeper than at Landshipping. It is, therefore, obviously impracticable to ascertain correctly the general succession of productive coal beds by sections made in any particular district.

At Amroth, for example, near the eastern extremity of the field, there is but one bed of workable coal, varying from 6 inches to 1 foot in thickness, while on following the coast cliffs westward to Tenby or the centre of the basin, the beds of coal multiply so rapidly, that at Wiseman's Bridge there are seven, varying from 4 inches to 22 in thickness. At Saunder's-foot the three principal beds occur in the following order:

| | Fath. | yds. | ft. | in. |
|---|---|---|---|---|
| Measures of shale, &c. | 10 | 0 | 0 | 0 |
| *Coal* 3 to 4 ft. | | | | |
| Measures | 6 | 0 | 0 | 0 |
| *Coal* 1 to 8 ft. | | | | |
| Measures | 18 | 0 | 0 | 0 |
| *Coal* 5 to 8 ft. | | | | |

The total depth of the shaft is 49 fathoms, and the dip nearly 45° southerly. This is one of the spots where, the strata not being violently contorted, the coal is largely and profitably extracted; but in the coast cliffs between Wiseman's Bridge and Amroth, the curvatures and breaks are so numerous, that although the outcrop is sometimes clearly exposed, the bed is persistent only a few yards, being lost amid convulsions of the strata.

Although I have spoken of the eastern culm tract as the most regular, the expression must be understood to apply to the general structure of the district, including the millstone grit and carboniferous limestone; the beds of culm being for the most part as much contorted as in the western tract, and to an extent, which those who have studied only the coal measures of the North of England, or of the central counties, cannot depicture to themselves. These phenomena are fully exhibited between Amroth on the east and Tenby on the west. At the latter place, indeed, a dislocation by which the lower part of the carbonaceous beds is brought into abrupt contact with the mountain limestone, is beautifully displayed[1].

### *Western Culm Tract.* (Pl. 35. f. 7.)

The carboniferous strata are continuous from Caermarthen Bay and the east of Pembroke, by Freystrop and other places, to St. Bride's Bay on the west coast.

[1] This fault is noticed by Mr. De la Beche. (Geol. Trans. N.S. vol. ii. p. 15.)

Now if any geologist was landed in St. Bride's Bay, and not having traced these coal measures from situations where they lie in *regular order of superposition*, was suddenly required to determine the relations of the various strata presented to him (as represented Pl. 35. f. 7.), he might well draw the most erroneous conclusions concerning the age of the culm beds, and pronounce them to be a part of what has hitherto been called the greywacke series[1].

Not only have these strata been dislocated and contorted in the highest degree, (much exceeding the irregularities east of Tenby;) but formations elsewhere separated by different deposits, are brought into juxtaposition. In the first place the carboniferous or mountain limestone is totally wanting; and the sandy strata, representing the millstone grit, often thin out, as expressed in wood-cut 73, p. 375. In this case the culm bearing beds repose at once and almost in conformable position on black schist of the Lower Silurian Rocks, much resembling in mineral characters, the culm shale; while near Brawdy the culm field rests upon, and has the *appearance* of graduating into the Cambrian System. (Wood-cut 74, p. 375.)

Now in both the last situations, there is so little appearance of *un*conformability between the culm strata and the Lower Silurian and Cambrian Rocks, and in many respects so much the appearance of a *passage* downwards, that any one, unfurnished with the key to solve such anomalies, might consider the culm strata to be part of the Cambrian and Silurian Systems. (See wood-cuts on the next page.) Yet nothing would be more erroneous than this conclusion; such culm strata being in truth the coal measures above the millstone grit, represented throughout the map by the letter *g*. In the county of Pembroke, for example, we can walk upon the same beds, from the district where they repose regularly upon the millstone grit (as represented in the upper wood-cut,) till we find them in this western tract in the anomalous positions expressed in the lower figures. (See Map.)

Such apparent anomalies are not, however, difficult of explanation, for geologists need scarcely be told, that when the formations which usually support coal-fields are absent, the lower carbonaceous strata, *must* of necessity resemble the rocks they rest upon, and out of whose detritus they have been formed. This reasoning, indeed, applies to rocks of all epochs, for numberless are the cases where strata, even of the tertiary age, resting directly upon gneiss and other primary rocks, assume the lithological characters

[1] These remarkable phenomena in Pembrokeshire first led me to suppose, that the views previously entertained of the structure of Devon were erroneous, and the above sections were those which I communicated to Professor Sedgwick, before we examined that county, with the view of determining whether the Devon culm strata were, as was then contended, subordinate to the so called "*grauwacke*"; or whether they were, like those of western Pembroke, of the age of the true coal measures, lying in an irregular trough upon various ancient rocks, into which they sometimes appeared (though deceptively) to pass downwards. The results at which we have arrived are now before the public. We had no hesitation in identifying the culm strata of Devon with those of Pembrokeshire and other coal-fields. See Proceedings of the Geological Society, vol. ii. p. 556.

of the oldest sedimentary deposits. The "arkose" of central France, where beds of the tertiary epoch (Eocene of Lyell), have the aspect of the oldest secondary or transition rocks, is an admirable illustration of this point[1].

The three following diagrams represent the principal different positions in which culm measures occur in Pembrokeshire.

S. Caermarthen Bay, East Pembroke. N. 72.

St. Bride's Bay, West Pembroke.

73. W.S.W. Nolton (W. Pembroke). E.N.E.

(*b*, *c* & *d* wanting.)

S. Near Brawdy. N. 74.

(*c*, *d* & *e* wanting.)

*a.* Culm Measures. *b.* Millstone Grit. *c.* Carboniferous Limestone. *d.* Old Red Sandstone. *e.* Silurian Rocks. *f.* Cambrian Rocks.

I have already stated enough to show, that sections made in different parts of the country will materially disagree in the order and succession of the culm bearing strata. Let any one desirous of studying this fact only pace the strand at low water from Druson Haven as a centre, and proceed southwards to Broad Haven and Little Haven, or northwards to Nolton and Newgale sands; and he will see a series of breaks, curvatures, thinnings out, and contortions, which cannot be exceeded even in imagination, and ought to be a warning to those who would speculate heedlessly in culm works, amid these convulsed strata.

Yet even in this neighbourhood there are spots, where the seams multiply and continue for *short* distances, and have been worked to some profit. One of the most remarkable of these productive tracts lies to the north of Nolton, where *nine* or *ten beds* (veins as they are here called) of coal have been wrought.. The uppermost is in the coast cliff, whence it bends to the north-east and south-east, and all the underlying seams, curling round conformably, rise in succession (about 2 ft. 4 in. in a fathom) and occupy the interior of the country between Simpson and Bathesland. (These are marked on the Map.) The ends of several of these coal beds can be traced on the sides of the Nolton Brook, whilst the underlying grits and flagstones emerge to the east of Nolton, where they are in contact, as above stated, with Silurian shale. (See wood-cut above.) Through the complaisance of Mr. Higgon, the chief proprietor of the coal mines of Nolton, who is beginning to work some of them in a spirited manner, I obtained the following list of strata as proved by various works.

[1] See the excellent work of M. Bertrand de Doue on the Puy en Velay; also Lyell and Murchison, "sur le Cantal." Annales des Sciences Naturelles, tome 18, Octobre, 1829.

certained by observing their order of superposition, we may, as I have already said, generally assure ourselves of the real age of such beds, when we find them void of Silurian organic remains, and still more easily, when we detect true coal plants in them. There is also another test, which though it may be empirical and unsafe as applied to larger tracts of country, is true as respects Pembrokeshire, viz., the much more abundant presence of iron, both disseminated and in smaller impure concretions than is found in the Silurian rocks. In this district, however, we have no need of such tests, for we can safely determine the age of these strata by following them up to a well-defined base line.

Thin coal seams, indeed, begin to appear even in these beds of Druson Haven, formerly called greywacke, and thence in the ascending order, culm is irregularly distributed throughout a considerable thickness of sandstone and shale, most of the beds, having after all, a very different lithological character from that of the Upper Silurian Rocks.

The other case above alluded to, is where the culm measures appear to pass downwards into the Cambrian Rocks. This occurs about half a mile north of the little stream which empties itself into the sea, by passing through the great shingle bank at Newgale Bridge[1]. Viewing the cliffs from the shore, it is no easy matter to define where the older strata cease and the younger begin, though on the one side of the depression are the Old Cambrian Rocks which range to St. Davids, on the other the true coal measures.

When the stratified masses of these two systems, which form the fringe of this bold coast, are looked at from the sea, or from the strand at low water, an artist, indeed, would naturally sketch them as lying conformably and dipping to the east of south at angles of about 40°. A gross error, however, would be committed in assimilating them, for on close examination the apparent conformity vanishes, and the mineral characters of the two classes of deposit is also seen to be distinct. To the north, the beds consist of purple, finely laminated, hard sandstone, like that of the Longmynd in Salop; to the south lies the millstone grit, consisting of grey sandstone, with some ferruginous matter and iron-stone concretions, a part of the carboniferous strata which dips under the productive culm strata of Newgale, Brawdy and Eweny. Further, the purple greywacke when accurately observed, is not strictly conformable to the coal grits; there being a perceptible discrepancy of strike (about 10° to 15°) between the one and the other, though they both have so nearly the same inclination as to *appear* conformable. Now if this junction were not exposed in a bold sea cliff, where the faces of these rocks are completely laid bare, how much might have been written upon *conformability* and *passage*! and what erroneous inductions might have been drawn from these fallacious appearances!

[1] The actual point of junction in the shore is marked by a depression in the cliffs. A small dyke or boss of trap is laid bare at low water, and partially alters and distorts the lowest of the carboniferous beds, which are hardened and highly ferruginous.

After all, however, though we are here presented with singular collocations, a geologist previously well acquainted with Siluria and South Wales, would have no great difficulty in marking the distinctions. In other parts round the northern lip of this coal tract, where it extends inland to the north of Brawdy and by Roche Bridge, the dark coloured culm measures being separated from the purple Cambrian rock, by a zone of unconformable, light coloured sandstone and millstone grit, there is an increased facility in drawing the boundary. The only real difficulty, therefore, in defining the exact demarcation occurs, as before stated, where the shale of the coal measures is directly in contact with the shale of the Silurian System.

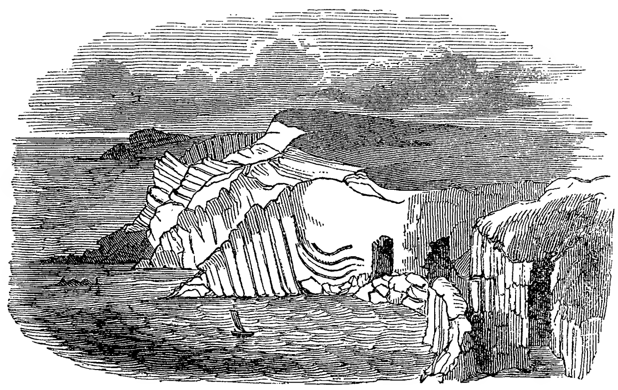
Amid the various dislocations to which these coal measures have been subjected, there is no one more striking, than that which occurs along the escarpment of a thin and broken zone of mountain limestone north of Johnston, where the strata of a coal-bearing tract dip to the south, while the carboniferous limestone on the south, plunges also in the same direction and therefore overlies the coal. Throughout the tract, indeed, included between Johnston and Haverfordwest, the culm which is worked from the natural outcrop to depths of seventeen fathoms, resembles that upon the coast in the amount of disturbance, the broken and contorted masses being termed "tumbling hillocks." Small culm is the only produce, and of this there is one good seam which is interstratified with flaglike shale overlaid by sandstone, grit and shale.

The phenomena of the inverted strata above described, is not confined to the west bank of the Cleddau; for on tracing these same culm measures on the east bank, we perceive precisely the same line of disturbance extending by Langam Ferry, where the whole of the productive culm measures lie in a reversed position, the younger rocks seeming absolutely to underlie the older.

Phenomena precisely analogous have been previously spoken of in Montgomeryshire (p. 309.), and similar examples will be hereafter pointed out in the Abberley Hills. In Pembrokeshire, indeed, as in Worcestershire, we can account for the inversion by the adjacent protrusion of volcanic rock, which has heaved the older strata into this unnatural position. Here also we have the advantage, of being able to follow the dislocated strata till they fall into their regular order, the culm measures resting regularly on the millstone grit and mountain limestone; and thus the extent and nature of the inversion are completely explained.

Before we take leave of the coal or culm-bearing measures of Pembroke, I may state that a numerous collection of their fossil plants, chiefly procured through the exertions of my valued friend, Mr. Leach of Milford Haven, has been examined by Professor Lindley, who is of opinion, that all these plants occur in other coal fields. They consist of various *Lepidodendra* and *Calamites*, most of which, from their fractured condition, are indeterminable, together with the common coal plants *Neuropteris gigantea, Pecopteris conchitica, P. nervosa, Sphenophyllum Schlotheimii, Stigmaria ficoides*, &c., &c. These are abundant in the Salopian coal measures, which occupy the same place in the

*Stackpole range of Limestone.*



76.

*Coast Cliffs near Bullslaughter Bay, from a drawing by Mrs. Murchison.*

In this tract the limestone occupies a greater space than in any other part of the county, having an average width of three miles, from Castle Martin on the north, to the precipitous coast cliffs on the south. Being flanked on three sides by the sea, the rock is exposed continuously in these cliffs for about eleven miles, and at each extremity it is in contact with the Old Red Sandstone.

There is no part of the coast of Great Britain where a longer continuous zone of the carboniferous limestone is laid open, nor is it any where so much contorted as in this promontory. The above vignette, and that at the head of the chapter, will serve to convey some notion of the contortions and fractures[1].

Though the cliffs seldom exceed a height of about 150 feet, yet as they are almost everywhere abrupt, and as their base can be visited only by a very few rude paths, they present a barrier as rugged and wild as any lover of bold scenery can wish to contemplate.

Some of the largest fissures by which the mass is broken up, run inland in parallel directions from 15° east of south to 15° west of north, and consequently transverse to the strike. They are seen in succession between the Saddle Head and other projections near St. Goven's Chapel, a hermit's cell, excavated in the face of the cliff, and accessible only by flights of steps[2].

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[1] The Countess of Cawdor was so obliging as to contribute a sketch of the cliffs near the Eligug Stack, a remarkable insulated rock occupied by myriads of sea fowl, chiefly the *Alca torda* (Linn.), provincially termed "Eligug." This sketch was missent, and I can now merely refer the reader to a coloured drawing of the same scene in Ayton and Daniell's tour round the coasts of Great Britain. This drawing has been recently copied by Leonhard in his work, Naturgeschichte der Erde, tab. 9. Stuttgart, 1836.

[2] Saint Goven (or St. Gawin) inhabited a cell cut in the face of this steep and picturesque cliff. Among his good deeds there is one which seems to connect his name with the geologist. His blessing conferred a healing virtue on the red clay or shale, derived from the decomposition of the limestone, which forms a talus

Besides these fissures, which are generally transverse to the main direction of the strata, there are many arches and caverns, some of which can be well examined in Bullslaughter Bay, also circular and elliptical funnels or swallow holes of considerable depth, similar to those described in the carboniferous limestone of Caermarthenshire. One of these, a short distance from the coast, not exceeding one hundred paces in diameter, contains within it a grove of luxuriant bushes and even lofty trees, the tops of which just reach the level of the bare calcareous platform on which no shrub can lift its head in defiance of the south-western gales[1]. There are also several cauldron-shaped cavities, to which the sea has access, one of the most curious, called Bosheston Mere, being situated about one hundred paces from the sea cliff. This narrow funnel communicates with the sea by one of the above-mentioned transverse fissures[2].

Having previously alluded to the lower member of the carboniferous limestone under the name of lower limestone shale, as brought out by undulations in East and West Angle bays, I may further state that other natural sections expose those strata and conduct us regularly downwards to the Old Red Sandstone. Thus in the coast cliffs, immediately to the east of Stackpole quay, such strata are interposed, though in almost vertical positions, between the limestone and the Old Red Sandstone, where in descending order they consist of

1. Thinly laminated black shale.
2. Ditto, with flattened nodules of calc spar and layers of calcareous grit, &c.
3. Thin bedded grey sandstone.
4. Thick bedded, hard, purple, compact sandstone.
5. Shale repeated with calcareous concretions.
6. Yellowish sandstone, with casts of shells and crinoidea.
7. Black shale and sandstone of greyish colour.
8. Red rab and sandstone (top of Old Red Sandstone).

In this deep creek the strata are partially reversed, a phenomenon for which the observer may be well prepared who has witnessed the contortions of the Stackpole promontory, but on following the

in a retiring angle of the cliff. The lame and blind pilgrims are still conveyed by their friends down the rude steps chiselled by the holy man, and after being anointed with a poultice, formed of the moist clay, are left there for several hours to bask under the summer's sun. The method of cure is similar to that effected by the *mud baths* of Acqui and Abano in the north of Italy.

The sanctum of St. Goven, a cleft in the rock just large enough to contain one person, is also much frequented as a "wishing place." The wisher is certain, before the end of a year, of obtaining his request, if he repeats it thrice, each time turning himself round in the narrow nook; but these and other miraculous stories, connected with this wild spot, do not come within my province.

[1] All the fine timber which ornaments the grounds of Stackpole Court, grows in combs or depressions, which thus present most striking contrasts to the bluff and bare headlands of the coast.

[2] In certain seasons, when a heavy surge sets in upon the shore, reports as loud as those of cannon issue from it, accompanied by discharges of spouts of water, which rise to a height of 40 or 50 feet above the surface of the ground. We may account for these phenomena by supposing, that when waves fill the innermost cavities, the water cannot entirely escape from these deeply seated tanks before they are again inundated, and being filled successively, they at length become surcharged, so that the water within being driven onwards by the impulse of fresh waves, issues at the point of least resistance and is ejected from the small funnel with the impetus of a forcing pump. Some of the larger and more open fissures, communicating with embayed creeks, resemble the Bullers (Boilers) of Buchan, Banffshire.

coast eastwards, the beds of the same age are again exposed in Skrinkle Bay, where, though very highly inclined, they repose on the Old Red Sandstone at an angle of 80°, and consequently decline beneath the great mass of limestone, ranging in the cliffs to Tenby. A similar order is observable in the interior of the south-eastern division of the county, along the escarpment of the limestone in the parishes of Mynwer and Marros, where yellowish sandstone with casts of shells and crinoidal impressions, immediately overlies and passes conformably into the Old Red Sandstone at angles of 30° to 35°.

In certain spots the limestone of the Stackpole coast is rich in fossils. It contains corals and two or three species of very beautiful unpublished small trilobites, all differing specifically from any which occur in the Silurian System.

In a collection presented to the Geological Society by the Earl of Cawdor, Professor Phillips and Mr. J. de C. Sowerby have recognised many species well known in the mountain limestone of other tracts. The species have been already enumerated, p. 161. It is worthy of remark that a portion of a *Cidaris* is among them, the *Echinidæ* being of very rare occurrence in this formation[1].

The lower limestone shale also contains fossils, and where they occur, the round impressions of encrinite stems, on the surface of the thin beds of yellow sandstone, give to the rock very much the rough external aspect of some strata of the Lower Silurian Rocks. I can, however, confidently assert, from specimens collected by myself in Angle Bay and also near Stackpole, that none of the organic remains found in these strata, which *rest upon* the Old Red Sandstone, agree in species with those of the Silurian Rocks beneath it.

In concluding these remarks upon the carboniferous limestone of this coast, I cannot avoid expressing my belief, that this rock constitutes the margin of a great coal-field, which has either been destroyed, or may, indeed, still exist in the area now occupied by the Bristol Channel; for however much the calcareous strata are contorted and broken, their prevailing inclination is southwards; i. e. they dip away from the Old Red Sandstone, and thus when viewed upon the great scale, they seem to form part of a vast trough, other portions of which occur in the Worms Head and southern headlands of the promontory of Gower, and also in the limestone cliffs on the eastern side of Swansea Bay[2].

### *Old Red System.*

The Old Red Sandstone of Pembrokeshire, as included between the carboniferous limestone and the Upper Silurian Rocks, differs in some details of lithological structure from the great mass of the system described in other counties. 1st. The attempt to subdivide it into precise formations (conglomerate and sandstone, cornstone, and tile-

[1] A *Cidaris* has, however, been observed in the limestone of this age in Scotland. (See Ure's Ruther Glen, Pl. 16. f. 7, 8. p. 318.

[2] A singular patch of pipe-clay and gravel on the surface of the Stackpole promontory, pointed out to me by Lord Cawdor, will be described in the concluding chapters on drift and alluvia, in which the blown sands and submarine forests of this tract will be also considered, and *Giraldus Cambrensis* referred to.

stone) cannot be sustained; a fact naturally to be expected, when it has already been shown that such distinctions are not maintained in the southern part of Caermarthenshire. 2nd. Although the rocks are for the most part of a red colour (*red rab*[1]), there are considerable tracts where they consist of grey and sometimes of yellowish sandstone.

Near Tavern Spite, where it enters Pembrokeshire, the Old Red Sandstone is thrown out into a promontory at Cyffic, the escarpment of which, as it rests against the Silurian rocks, trends from north-east to south-west, whilst the upper member of the same mass folds round to the south-east, encircling and dipping under the carboniferous limestone and coal measures of Amroth and Tenby. This mass of Old Red, taking an east and west direction and tapering away in its course to the west, wedges out and disappears at the eastern end of Mynwer Wood, on the left bank of the river, opposite to Slebech. This is the only large development of Old Red Sandstone which lies to the north of the great coal-field. All the other districts occupied by this rock are to the south of it; either immediately underlying the coal bearing strata between Tiers Cross and Rosepool in the western district, or accompanying and supporting the carboniferous limestone in long continuous ridges. Examples have been already cited, where the overlying limestone passes down into this formation, and we may now state, that the lower members graduate into and repose upon strata of the Silurian System. (See Pl. 35. f. 6.)

The upper part of the system which graduates into the lower limestone shale, as seen at Sawdorn in East Angle Bay, consists of the ordinary, dull red, argillaceous shale, provincially termed "red rab," alternating with courses of grey and greenish, flaglike sandstones. These are underlaid by other beds of the red rab, containing subordinate thick strata of quartzose red conglomerate, the pebbles being occasionally of the size of a man's fist. I have not observed these conglomerate beds in many other parts of South Pembrokeshire, though they are here precisely in the same situation in which they occur in parts of Monmouthshire and Gloucestershire, where they are separated from the overlying limestone by courses of red and grey sandstone, shale, &c. (Pl. 35. f. 1.)

In a section recently laid bare between Hobbs Point and the narrow spur of limestone of Pembroke Dock, the upper members of the formation are composed of thin, flaglike, reddish, sandy shale, passing down into grey and purple, hard, micaceous sandstone, the ordinary dull red rab re-occurring at intervals. A similar succession is observable in all the transverse sections from this Pembroke band of limestone to the promontory of Cosheston, for though the prevailing sandstones are yellow, they alternate with red rab under Cosheston Church and pass conformably under the carboniferous limestone. The same peculiarities of *colour* may be equally seen in the northern district, south of Cold Blow, where courses of yellow sandstone of considerable thickness alternate with red rab, but the former so exceeds the latter in quantity, that the yellow colour prevails over the red, in a great breadth of surface. In most of these cases, however, zones of red rock are interposed between the yellow sandstone and the lower limestone shale.

These yellow and grey sandstones occupy a considerable area in other places; as in the greater part of the promontory of Cosheston, with the western bank of this part of the Milford estuary, occupying Williamston Mountain and Burton parish. The sandstone is generally flaglike and micaceous on the surface of the laminæ, and sometimes contains green blotches of marl, and very rarely a few fragments of carbonaceous matter. The beds are frequently of a foxy, yellow colour, and decompose to a sandy, sterile soil, which as it exhibits very few traces of red rock, might lead

[1] "Rab" is sandy shale.

those who had not worked out the relations of the system to conclude, that these strata belonged either to some lower portion of the unproductive coal-field or to the Silurian System[1]; but close examination has convinced me, that these beds are an integral portion of the system of Old Red Sandstone. 1st. They contain at intervals masses of true red rab which *alternate* with them until the whole passes conformably into the lower limestone shale. 2nd. They are not only lithologically distinct from any Silurian rocks but they *never* contain a trace of the organic remains so abundant in that system. 3rd. They pass down into certain greenish grey, hard, flaglike, micaceous sandstone, which has been shown to constitute the base of the Old Red Sandstone over large tracts in the Clyro and Begwm Hills, Radnorshire, Herefordshire, &c. (p. 181.) 4th. Although such yellow sandstones are uncommon in the Old Red Sandstone, their occurrence has been pointed out in other counties, particularly at Prescot Bridge near Cleobury, Salop (see p. 174.), whilst some of the grey and flaglike beds with fragments of plants are precisely similar to the strata near Bromyard. (see p. 177.)

The colour of the great mass of the formation in Pembrokeshire, particularly in the central and lower portions, is red; the rocks consisting of thick and thin-bedded red rab, with occasional courses of good building sandstone. Strata sufficiently calcareous to represent cornstone are very rare, though a few occur among the variegated red and green marls near Wollaston Cross, near Pwll-y-crochan, south of Milford Haven; also in the mottled marly beds alternating with sandstone, in the deep ravines between Narbeth and Tavern Spite, particularly in that of Cilrhiw[2]. One variety of this concretionary rock consists of bluish green shale, with yellowish spots of calcareous matter, which upon decomposing give it a cellular appearance. Few, perhaps none of these cornstones are sufficiently calcareous to be burnt for lime.

Instructive sections of the lowest beds of the formation are visible in the deep and narrow combs which furrow the great dome-shaped mass of Old Red Sandstone of the parish of Cyffic (east of Tavern Spite). In several of these, especially on the north side of the new road to Caermarthen, the uppermost beds of the Silurian System crop out from beneath the Old Red Sandstone and define its base precisely. Here, dull green and yellow, flaglike beds, alternate with red rab, and are succeeded by mottled red and green, sandy, argillaceous strata, of concretionary structure, which even in the freshly quarried faces present a honey-combed and rotten aspect, a variety of the Old Red Sandstone which is almost peculiar to Pembrokeshire, and in conjunction with beds of quartzose conglomerate having a greenish base, reappears frequently throughout the range of the formation to the westward. The cavernous structure arises generally from the decomposition of the less tenacious concretions of marl, though there are also cases of half concretionary, half conglomerate beds, from which quartz pebbles fall out and contribute to give this aspect. Commencing at Pont-ar-llechau in Caermarthenshire, where such a structure was first noticed, the inferior members of the strata at intermediate places have been observed frequently to contain hard quartzose conglomerate. A clear section of this occurs in Canaston Wood south-west of Narbeth.

*a.* Thick-bedded, mottled and porous red rab, without mica.

*b.* Flags of greenish grey grit, faces covered with plates of white mica and traversed by veins of white quartz, passing into

*c.* Hard (*greywacke*-like) grit, in parts almost a conglomerate of grey and greenish grey quartz pebbles, fragments of slate and Silurian rocks. Beds one and a half to three feet thick with way-boards of yellowish green shale, in all twenty feet thick. This stone, being the hardest in the neighbourhood, has been largely extracted in constructing the new roads.

*d.* Thick-bedded, cavernous, mottled, concretionary, red and green rab, in parts calcareous and resembling impure cornstone. *e.* Red rab, passing into

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[1] Formerly mapped as greywacke.

[2] The residence of Mr. Baugh Allen.

*f.* Argillaceous, thin-bedded, light-coloured sandstone, very slightly micaceous with a profusion of casts of fossils, of which notice will be taken in treating of the Silurian rocks.

This section is quoted, to show the place of the lower conglomerate (*c*), which, although interpolated in the Old Red System, is perfectly undistinguishable from some of the oldest coarse grits of the Cambrian System; for the description of the concretionary masses and beds of quartz grit west of Llandovery, and extending thence to Rhayder in the heart of the old slaty rocks, might well be substituted for this bed, either of them being perfect specimens of German "greywacke." This circumstance is specially insisted upon, to demonstrate the absurdity of retaining this word in *geological* nomenclature[1].

Conglomerates like this of Canaston Wood, occur in vast quantities upon the surface of the high and sterile tract north-east of Tavern Spite, near the junction with the Silurian rocks. They are also seen at Rushford, north of Hoton, where the Silurian rocks protrude, and again at several points in the southern or Pembroke promontory. They are for the most part easily separated from a much coarser and more angular, grey-coloured conglomerate, which occurs occasionally where certain Silurian rocks have been protruded. The latter is not underlaid by a great thickness of red shale or rab, like the true conglomerate of the Old Red, but forms a part of the fossiliferous strata of the Silurian System. The other situations where the Old Red Sandstone may be observed incumbent on the Silurian rocks, are in the coast cliffs of Freshwater East and Freshwater West, and here again the two sorts of conglomerate occur, the one in the Silurian rocks along the line of fault, the other in the Old Red. But the most instructive section of a complete passage from the one system into the other is at Hook Point, the southern headland of Marloes Bay. (Pl. 35. f. 10. and p. 392.) Here the same honey-combed, sub-concretionary beds, with red rab and sandstone, pass down into and alternate with grey beds, until they are fairly dovetailed into strata of unequivocal Ludlow rock, the top of the Silurian System. The absence of conglomerates in these beds of passage, in so complete a section as that of Marloes, harmonizing with the regular sequence of the same beds near Tavern Spite, teaches, that the conglomerates must have resulted from partial dislocations, and as some are seen within the Silurian System and others in the Old Red, they indicate the occurrence of disturbances at different intervals. It is obvious, however, that such conglomerates may have been formed by ancient tides and currents. But in whatever manner accumulated, whether by torrents, resulting from elevations and dislocation, or caused by diurnal action, it is evident that the old conglomerates in question were purely *local*.

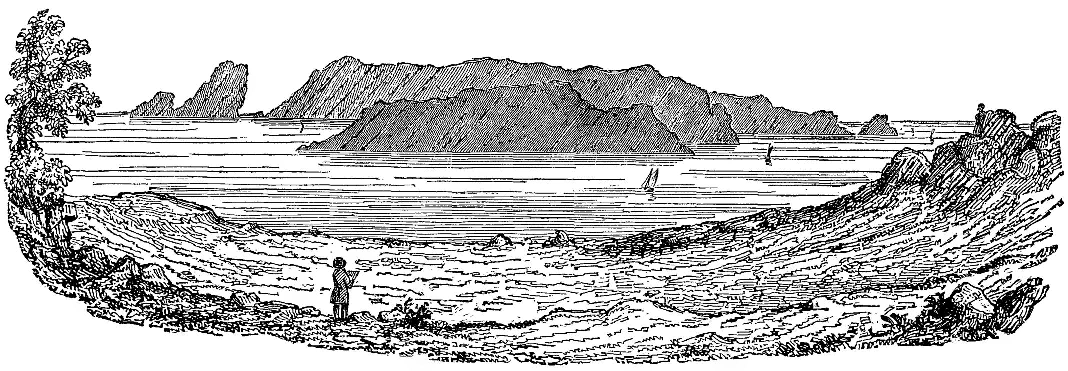
No organic remains have yet been detected in the Old Red Sandstone of Pembrokeshire. This is perhaps to be expected, as it contains scarcely any of those beds of true cornstone or calcareous flags in which the greater part of such remains, particularly the fishes, are found. The absence of calcareous matter is, indeed, the great cause, why some tracts of this red rab do not afford so warm and rich a soil as the mellow lands of Herefordshire[2].

[1] If I were disposed to extend the application of these remarks, I might I believe assert that rock specimens, which many mineralogists would term greywacke, may be found in every stage of the geological series, even in the tertiary deposits. Geologists who have worked out the general relations of a country are of course exempted from this remark.

[2] Speaking of some of his red land, near Wollaston Green, a farmer observed to me, "it eats all the manure and drinks all the water:" although this homely remark was very descriptive of the district in question, there are wide tracts where the red rab decomposes to excellent land, perhaps the best in Pembrokeshire.

The great ruptures in this formation are well displayed in the cliffs of Milford Haven. To enumerate all these faults and breaks would be tedious if not impracticable. One remark, however, is essential: the strata on the opposite sides of the estuary, either where it is broad, or towards its upper extremities about Lawreny, where it narrows to the width of a river, have never the same dip, being tilted in opposite or divergent directions; thus proving, that this magnificent, land-locked estuary, quite unparalleled in Great Britain for the depth of its water and the security of its haven, was produced by a violent rupture of the strata. (See arrows on the map indicating the dislocations.)

In the next chapter we shall consider the Silurian, Cambrian and Trap rocks of this county, concluding with some general observations on the direction of the deposits.





*Skomer Island, as seen from Wooltack Park, from a sketch by Mr. Francis Leach.*

# CHAPTER XXX.

## PEMBROKESHIRE (*continued*).

*Silurian System.—Divided into Upper and Lower Silurian Rocks, with full developments of the Caradoc and Llandeilo formations.—Cambrian System and Slaty Rocks.—Trap Rocks, bedded and amorphous.—Divergent lines of strike explained by eruptive ridges of trap.* (Pl. 35. figs. 1, 4, 6, 10, 11, and 12.)

IN the last chapter we have proceeded in regular descending order, from the surface of the coal-measures, as being the youngest strata in Pembrokeshire, till we reached those rocks which have been traced without interruption, from Shropshire to the western borders of Caermarthenshire.

The order in which they are arranged, and the organic remains which they contain, clearly mark the age of the Silurian rocks in this district. Their aspect, however, and their relative proportions of sandstone, limestone and shale, vary so much from those in the strata selected as types in Shropshire, that it is not often practicable to make those distinctions which enabled us elsewhere to subdivide the system into formations. Thus, though certain gray rocks with fossils, occupy the place of the Ludlow formation, yet they are, for the most part, unlike the rock of Ludlow, being harder and more siliceous; whilst in the absence of any subordinate course of limestone, like that of Aymestry, we cannot attempt to separate the formation into upper and lower portions. In like manner, though *the place* of the Wenlock limestone is clearly manifested in Marloes Bay, it is rarely to be known by its lithological structure, being for the most part hard and slaty; though

the principal coast section in which this system appears, affords us one example of shale, in parts calcareous, containing the usual corals and some of the shells of this formation. With such variations in the Upper Silurian Rocks, the Lower Silurian possess, on the contrary, their usual mineral impress, and many characteristic fossils; the limestone of the age of that of Llandeilo, swelling into masses of even greater thickness than in any previous part of its course. Under these circumstances, as it is not always possible to define the course of each formation, I shall first describe the system, as in Caermarthenshire, under the heads of Upper and Lower Silurian Rocks, in doing which I shall indicate those points where the strata can be identified in greater detail.

### *Upper Silurian Rocks.*

These rocks, though forming only slender bands, rise, as already stated, with distinctness on the eastern borders of Pembrokeshire from beneath the Old Red Sandstone of Cyffic and Tavern Spite. The peculiar junction beds of the Old Red Sandstone, before described, are succeeded by thin-bedded, finely laminated, argillaceous sandstone, sometimes ferruginous, and the laminæ of separation occasionally coated with black oxide of iron. They graduate downwards into other thin, grey, sandy strata, some of which are flaglike and calcareous as at Parkau, between Tavern Spite and Llandwror. These beds are not very fossiliferous, but I have detected the *Calymene Blumenbachii* and *Terebratula Navicula* of the Ludlow formation. Though such relations of the Silurian rocks to the Old Red Sandstone are observable to the east and south-east of Cyffic, on the sides of both the old and new road to St. Clears, the section in descending order is suddenly disconnected by a powerful dislocation, ranging from south-west to north-east, along the north-western face of these elevated tracts, whereby the relations of the Upper to the Lower Silurian Rocks are much obscured and overlaid by detritus. This line of elevation, it will be observed, is at right angles to another which passes along the valley of the Taaf.

The passage of the Old Red Sandstone into the Upper Silurian Rocks is again well seen at Narbeth. A transverse section from the edges of the Old Red Sandstone to the highly inclined Silurian strata on which the castle is built, presents in descending order sandy, yellowish red grits with a base of felspar, constituting the junction beds of the Old Red Sandstone, succeeded by dull greenish and ferruginous, micaceous, soft, thin-bedded sandstone, passing into fragile, sandy, grey flags with shale, and containing under the castle a few fossils (such as *Calymene Blumenbachii, Asaphus caudatus, Terebratula Navicula*). As the dip varies from 70° to 90°, a considerable thickness of strata is represented in the short transverse section exposed on the sides of the road. (See Pl. 35. f. 4.)

To the westward of Narbeth the junction of the Silurian rocks and the Old Red Sandstone is so obscured by dislocation and denudation, that it is impossible to determine precisely the age of each underlying stratum which is successively brought into contact with the Old Red Sandstone. Thus at Canaston Wood[1] the fossils contained in the Silurian Rock compel us to place it in the Caradoc

[1] Among the fossils at Canaston wood are *Productus sericeus, Orthis radians, Orthis aperturata, Orthis elegantula*, Dalm., *Spirifer*, n.s. All these species are found in Shropshire, Radnorshire, and Caermarthenshire, in beds of true Caradoc sandstone.

sandstone, whilst at Milling the *Asaphus caudatus* and other fossils would indicate that the shale which abuts against the carboniferous limestone is of the age of that of Wenlock.

Let us now view these rocks as presented on the coast. In the southern or Pembroke promontory they rise in highly inclined strata from beneath the Old Red Sandstone, appearing in the bay of Freshwater east, whence they traverse to Freshwater west, thus at each extremity of the promontory occupying a bay of about one mile in width. Another spur of these rocks is prolonged from Freshwater west along the valley of Castle-martin-gorse, to the pleasure grounds north of Stackpole Court, where a fossiliferous sandstone subsides beneath the Old Red Sandstone. At Freshwater east, where the relations are clear, the Old Red Sandstone is thrown up on both sides into so highly inclined positions, that the Silurian rocks are better exposed. At the eastern side of this bay, the junction is obscured by blown sands, and there is probably a fault, though some of the beds of Old Red Sandstone, consisting of yellow and greenish sandy flags with red way-boards, dip off 70° to the north, the strike of the strata being 10° north of west. The inclination of the Silurian rocks increases to the centre of the bay, where beds of sandstone charged with fossils rise out at the back of the hills of loose sand in almost vertical positions, whilst in the western cove on the other side of the bay, in approaching the contact with the Old Red Sandstone, beds of dull greenish grey sandstone with little or no mica and with a few casts of fossils dip to the south-west at 45° or 50°.

From this spot the Earl of Cawdor procured the following remains,—*Leptæna depressa?* (imperfect cast of) *Leptæna rugosa, Spirifer* (sharp plaited species), *Atrypa tumida?* Dalm., *Cucullæa Cawdori*, N. S. The last named shell, being the first example of that genus found in a rock of so high antiquity, I have named it after its discoverer. A small species of trilobite also occurs, and it is essentially different from any form known in the carboniferous limestone. (See Pl. 35. f. 12.) The overlying beds consist of a grey conglomerate of coarse angular fragments of Silurian rocks with rounded quartz pebbles, and plunge under the red sandstone.

This spot is the scene of faults, since the strike of the Silurian beds is 35° north of west and 35° south of east, and that of the Old Red is 10° west of north with a dip to the west. The coarse conglomerate in the Silurian rocks is not however confined to this locality, for it sweeps in a strong band along the flanks of the Old Red Sandstone, passing by Thurtle Mill and Dry Barrows on the west, and reappearing from beneath the blown sands of Newton Barrows, it runs out in strong ledges in the northern side of the bay of Freshwater west. Similar relations of this coarse grey conglomerate are seen in the northern side of the valley of Castle-martin-gorse, near Corston House and Stem Bridge, and it may, therefore, be recognised as marking the edge of the Silurian rocks through this tract. Though we find traces of the Silurian rocks on each side of the bay of Freshwater west, similar to those mentioned at Freshwater east, exposed at low water and dipping to the north and south at high angles beneath the Old Red Sandstone, the underlying beds which once occupied the centre of this bay have been denuded.

The coarse conglomerate here mentioned, must not be mistaken for the conglomerate which in Pembrokeshire, occurs in the lower division of the Old Red Sandstone, the pebbles in which are smaller and more rounded, and its matrix similar to that of all the red sandstone conglomerates. Nor are these Silurian conglomerates which rise up in narrow belts through the Old Red Sandstone between Freshwater east and Freshwater west of great extent, for in the full development of the Silurian System in Marloes Bay, which I now proceed to describe, there is no trace of them.

78.

*Marloes Bay.* (See Map.)

The western shores of Broad Sound, of which Marloes Bay is a part, present a full succession of all the rocks of the Silurian System, from their junction with the Old Red Sandstone at Hook Point, to their passage into strata of the Cambrian System in the extreme headlands of Wooltack Park and the Isle of Skomer. This transverse section exposes the strata rising from beneath each other for not less than two miles, dipping to the S.S.E. at an average angle of at least 45°. The thickness of the Silurian System in this one spot is, therefore, very considerable, though it occupies so small a breadth upon the map.

The above wood-cut represents the upper portion of this series, surmounted by the Old Red Sandstone. The lower strata, associated with trap, appear in the vignette, p. 389.

## *Descending Section (Marloes Bay).* (Pl. 35. f. 10.)

Red and green rab or base of the Old Red Sandstone, alternating with grey sandstone, as seen at the end of the above wood-cut and coloured section. (Pl. 35. f. 10.)

1. Dull greenish grey sandstone and schist, in parts argillaceous, very minutely micaceous, and not unlike the Upper Ludlow Rock, except in being harder and thicker bedded, dip 35° S.S.E. It passes upwards into the red rab.

2. A succession of thin-bedded sandstones and shaly beds of various colours, some weathering to deep ochreous yellow, others to white. They contain casts of fossils, including *Crinoidea*, &c. As these beds are on the whole much softer than No. 1, they have been worn into a cove by the sea. They are in parts pyritous.

3. Hard, finely laminated, grey, slightly calcareous sandstone of considerable thickness, traversed by white veins of crystallized carbonate of lime, with imperfect casts of trilobites and other fossils. In part a slight conglomerate appears, with sandy courses, the edges of which are marked by protoxide of iron, which occurring in blotches somewhat resembles carbonaceous markings. Corals very abundant.

4. Hard thick-bedded grey sandstone with white quartz veins.

5. Calcareous sandstone and shale, with veins of white carbonate of lime, with many corals, particularly in the upper parts. The beds dip about 65°, whilst the planes of slaty cleavage dip 85°. N.B. The cleavage planes are visible in the schistose beds only, being imperceptible in the intervening strata of thick-bedded sandstone. (See wood-cut, note, p. 360.)

6. Beds 3 to 4 feet thick, more or less calcareous, with corals, imperfect casts of shells, *tentaculites*, and trilobites, probably heads of *Calymene Blumenbachii.*

7. Bands of ferruginous thin-bedded sandstone, with beds of intervening shale; where the latter is worn out, the highly inclined sandstones form the top of the cliff, and are called the "Three Chimnies." A slaty cleavage, oblique to the lines of stratification, is impressed upon the mass, and a few quartz pebbles mark the laminæ of deposit as they approach towards

an irregular boss of trap rock which here rises into the cliff. This trap will be described in the sequel. In a few paces beyond this intrusion the regular succession is renewed.

8. Dark grey shale with calcareous concretions, some of which pass into thin courses of grey limestone. On the surface of these are many fossils belonging to the Wenlock limestone, including *Terebratula affinis, Orthis radians, Atrypa aspera, Spirifer lineatus, S. radiatus*, and a new species found at Dudley. Portions of *Trilobites, Crinoidal stems, Orthoceratites* with remote joints, unnamed conical tubes occurring at Dudley, together with many of the *Corals* of this formation, and some very peculiar organic bodies which will be described in subsequent chapters.

These fossils clearly prove, that the band No. 8 is the equivalent of the Wenlock limestone, and hence the overlying strata from 1 to 7 inclusive must represent the Ludlow rocks, and although they are not charged with as many organic remains as in Salop and other parts of their range, yet they here occupy a considerable zone.

The Wenlock shale with nodules and fossils, as exhibited in a little cove, is underlaid by other sandstones and shale No. 9, which from their imbedded fossils belong to the Lower Silurian Rocks.

Such are the rocks representing the upper portion of the Silurian System in these coast cliffs. They range inland across the promontory of Marloes.

## *Lower Silurian Rocks.*

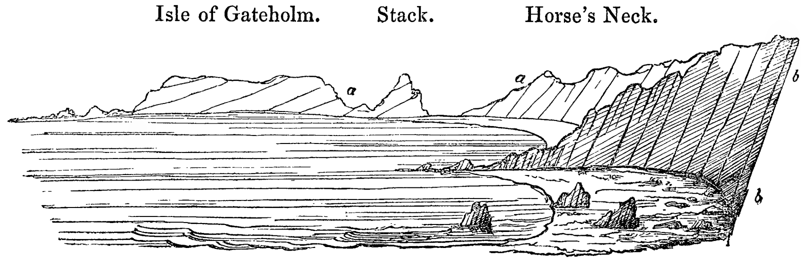
We cannot better commence the account of these rocks in Pembrokeshire than by continuing the instructive section, in descending order, afforded by the cliffs of Marloes Bay.

9. The strata which rise from beneath the grey shale with Wenlock corals, and occupying the coast at Marloes Mill, consist of hard, thick-bedded, grey sandstone, with white quartz veins and shale, followed by other sandstones somewhat calcareous, having on their surfaces ripple marks, and their mass is traversed by veins of white calcareous spar.

10. They pass downwards into sandy schists, which are abundantly charged with casts of the fossils characteristic of the Caradoc sandstone, such as the well-known coral of May Hill and other places, with numberless circular impressions of the ends of encrinital stems.

These beds, as well as those of the overlying Wenlock shale, are impressed with a transverse slaty cleavage, which cuts through and so distorts the fossils, that fragments of these rocks might be referred to strata of as high antiquity as the rocks of Snowdon. Attention has been previously directed to similar changes in the lithological aspect of rocks of this age near Caermarthen, and such examples, we repeat, ought to act as powerful warnings against all attempts to identify the age of formations by their external characters. To the west of Marloes Mill is a fault by which the Old Red Sandstone of the Isle of Gateholm, with a small tongue of the same on the mainland, is brought into contact with these Caradoc sandstones, thus:

79.




*a.* Old Red Sandstone. *b.* Caradoc Sandstone with slaty Cleavage.

The Caradoc sandstones range from this point all along the wild coast cliffs of Marloes Mire, rising in unbroken and regular succession for upwards of a mile, the hardest beds sometimes forming headlands, as at the Rain Rock, and where the sandy shale prevails being scooped into caves. The angle of inclination varies from 50° to 65°, the strike being W.S.W and the dip S.S.E.

Slaty cleavage prevails more or less throughout this vast succession of strata, but is not perceptible where the sandstone is thick-bedded. Innumerable joints occur in many of the masses, and they seem to increase in number near points of violent dislocation, as near the great fault of Gateholm Isle, where the dominant joints trend with the dip, ranging from 35° east of south to 35° west of north, or transverse to the strike.

## *Llandeilo Flags.* (No. 11 of Coast Section.)

The Caradoc sandstone seem to have its natural termination about a quarter of a mile to the east of Wooltack Park, the most western promontory of the mainland, where it graduates down into thinly laminated, blue and greenish schist and flagstone, containing some of the fossils found in the lowest Silurian rocks. At this point the cliffs are so difficult to examine, that I could not detect any well recognised trilobites; but in the creek of St. Bride's Bay, called Muscle-wick Mouth, on the opposite side of the promontory, and dipping beneath the great mass of Silurian strata above described, I had great satisfaction in discovering a considerable mass of true Llandeilo flags. They are exposed for upwards of half a mile, in cliffs easy of access at only one or two spots. They can, however, be descended by rugged paths, in one of which, called the Welchman's road, I found specimens of the *Asaphus Buchii, A. Tyrannus,* and a species of *Trinucleus.* The flags are of their usual dark colour, but they are more sandy and less calcareous than in parts of the county through which we shall presently trace them. They are indeed chiefly made up of black, finely laminated, shivery schist, with occasional strings, veins, and concretions of black and white calcareous spar. They dip about 35° to S.S.E., and thus plunge under the greater mass of the Silurian System of the Marloes promontory. At this spot, the Llandeilo flags are penetrated and partially overflowed on their western flank by porphyritic greenstone. On the north, where they are in contact with the Old Red Sandstone, the thinly laminated beds become thick masses in which traces of bedding are with difficulty observed, and altogether they are much altered, indurated, and traversed by many veins, so I had little doubt that trap rock, though not visible, lies at very little depth beneath. On the south, indeed, the beds are abruptly cut off by the trap extending from Marloes by West Hook to the Hays Point, which rock appeared to break through and overlap these beds, but I could not descend the cliff at the point of intersection. As the relations of these Llandeilo flags of Muscle-wick Mouth, to the Old Red Sandstone and the trap, are highly interesting, they are explained in a separate diagram. (Pl. 35. f. 11.) The whole of this mass of Llandeilo flag has a slaty cleavage, inclined at angles of 70° to 80°, dipping in the same direction as the beds, and as the latter fold over from verticality to angles of 35°, the planes of cleavage and the laminæ have an apparent coincidence at one point. (See further observations on this head towards the close of this chapter.)

Enough has now been said to show the existence in the coast cliffs of Marloes of a great succession of fossiliferous strata, among the lowest of which are flags containing the fossils of the Llandeilo formation. Beds of sandstone, however, unquestionably older than these Llandeilo flags, rise out in the furthest western rocky peninsula of the mainland called Wooltack Park. They consist of hard quartzose grits and sandstones with a few impressions of encrinites, and they may be considered, like those described near Llandeilo, as the true beds of passage into the Cambrian

System, which rises in thick stratified masses both near the western extremity of the mainland, and specially in succeeding lower shelves in the adjacent island of Skomer. (See Vignette, head of this chapter, and Pl. 35. f. 10.) These rocks, however, are associated with much trap, which is sometimes arranged parallel to the strata, and at other times intrusive; but of these we shall speak hereafter. Having described those parts of the coast at which the Silurian formations are exposed, I may now recall attention to those tracts where the lower rocks of the system appear in the interior of the county.

### *Caradoc Sandstone—inland course. Orlanton and Hoten Band.*

This is a narrow band of Lower Silurian Rocks, less than half a mile in its greatest width, which has been heaved through the Old Red Sandstone for upwards of three miles, from Orlanton on the west, to the upper end of Spread Eagle Pill on the east. At Mallock Slate Mill, the beds are rotten argillaceous sandstone, nearly vertical, containing *Leptæna sericea*, &c. At Hoten they are associated with hard quartzose grits, plunging 45° south, and the band subsides beneath the Old Red Sandstone in a point near Spread Eagle Pill. They are, however, for the most part, perishable, shelly sandstones, with imperfect slaty cleavage, and contain among other fossils the well-known *Orthis bilobata*, so abundant in all the rocks of this age from Shropshire and Montgomeryshire, to the south-western extremity of this county.

### *Johnston Band.*

Another insulated band of Caradoc sandstone, double the length and width of that of Hoten, extends also from west to east to the south of Johnston, reaching from Romans Castle on the west (where it is penetrated by trap rock) to a point near Dumpledale, between Rosemarket and Langam. In the eastern part of its course this band is flanked on each side by ridges of trap, but on the whole of its southern border, ranging by Tearson, Redstock, Harmeston, and Hayston Mill, and also at its north-eastern extremity, for a short space at Dumpledale, it is in contact with Old Red Sandstone. In this band, among numberless impressions of encrinites and the fossils previously mentioned, I found the *Pentamerus lævis*, so characteristic of the upper portion of the Caradoc sandstone. The prevailing inclination of these beds is to the south, but in the narrow zone, between the two ridges of trap south of the Trooper's End, they are thrown in discordant directions, as seen in two small combs above Nash Mill.

### *Haverfordwest Band.*

The Caradoc sandstone is fully and clearly displayed in the cliffs on both banks of the river at Haverfordwest, where it sometimes runs in vertical strata from east to west, and supports the greater portion of the town, while in the western and southern suburbs it constitutes arched promontories, one of which runs out with a south-westerly strike to the Maudlin Bridge, where, dipping to the south-east, it abuts against the millstone grit of Poorfield. The rock is composed of imperfect, argillaceous flagstone, with much shivery schist, passing occasionally into concretionary masses. Courses of solid stone are rare, the most persistent masses ranging from the castle of Haverford on the east to Sutton on the west. Among the fossils I observed *Orthis bilobata, O. grandis, Terebratula lacunosa* (Schloth.), &c.

These sandstones with much incoherent shale are traceable to the westward of Haverford, through Sutton and Stember Commons, to the flanks of the Nolton coal-field, near which they contain *Trinuclei*, trilobites peculiar to the Lower Silurian Rocks. To the eastward they pass to the north of Narbeth by Arnol's Hill and Robeston Wathen, from which point they become much attenuated and give way to a great expansion of Llandeilo flags.

The great dislocations which have taken place along the southern frontier of the Silurian System, in its course from Narbeth to Haverfordwest, have been already alluded to; and it has been shown, that although the uppermost Silurian rocks are exposed at Narbeth, yet at most of the intermediate places upon this line, there are such breaks in the succession, that the strata of the age of the Caradoc sandstone, carboniferous limestone, and Old Red Sandstone are brought into contact. These dislocations seem to have increased in intensity in that great elbow into which they have been thrown to the north-east of Narbeth. (See Map.) Instead of a well-developed zone to mark the Upper Silurian Rocks, like that which has been pointed out in other places, we there find the break has been so powerful, that not only can we observe no traces of the rocks which are so largely exposed within three or four miles, forming a passage into the Old Red Sandstone, but the latter is thrown off in a great dome-shaped mass, flanked on the north-west by a very slender band of grey sandstone and shale, which alone separates it from the Llandeilo flags. (Pl. 35. f. 6.) This is most clearly seen in crossing from Cirlhiw by the Land Mill, or in any parallel traverse from the old red of Cyffic and the hills north of Tavern Spite to the parish of Llampeter Felfrey; and, although, for the most part, the line of junction between the Old Red and Silurian Systems is obscured by vast accumulations of detritus, in several spots are indications of faults, producing unconformable positions of the strata. One of the faults, passing to the north of Cirlhiw by Land Farm, has a direction from 10° north of west to 10° south of east, whilst another, traceable from Pen-a-bac by Cwm-coaly, trends from north-east to south-west.

We may presume that the hard quartzose and flaglike grits, quarried at Middleway, and ranging thence by Pen-y-graig to the woods above the Taaf, form a portion of the Caradoc sandstone, since they greatly resemble those of Llandwror in the adjacent part of Caermarthenshire, and occupy the same place in the series. These, being upon a line of great dislocation, are arched, snapped off, and in one part being thrown over, they dip north-west at an angle of 60°.

### *Llandeilo Flags and Limestone—inland course.*

The fullest development of the Llandeilo flags in Pembrokeshire, and the largest masses of limestone associated with them, are displayed in the parishes of Llampeter Felfrey and Llandewi Felfrey. The formation is there nearly three miles wide, occupying two tracts, of undulating fertile hills, separated by a brook, which flowing from south-west to north-east, falls into the Taaf near Pont-loyria. The subordinate limestone is similar to that of Clog-y-frain in Caermarthenshire (p. 358.), from which it is separated by a denuded tract from three to four miles in breadth, through which the Taaf winds, and in the centre of which is the village of Eglwysfair. This valley of elevation marks powerful dislocations corresponding to the great fault by which the Cyffic promontory of Old Red Sandstone has been projected to the north-east, for by inspecting the map it will be seen, that as the limestone of Clog-y-frain trends from

north-west to south-east, the same rock when it reappears at the Ffron and Llandewi ridge, strikes at a right angle to its former direction, viz. from north-east to south-west, whilst the ridges of Llampeter Felfrey run from east to west. These converging directions soon render the two ridges confluent, so that when viewed on the map they appear like the prongs of a fork. Their union takes place to the north of Croynwydd and Narbeth, whence the calcareous strata in their further prolongation, conform to the westerly direction of the rocks in the central part of Pembrokeshire.

The upper portion of these Llandeilo flags at the Land Mill near Cilrhiw, consists of vertical beds of sandy flags with calcareous courses, the mineral characters agreeing precisely with those in the upper beds at Golden Grove near Llandeilo, and the fossils are also identical, namely, *Orthis canalis*, with corals, and abundance of fragments of trilobites, including the *Trinucleus Bigsbii* and the large *Asaphus Buchii*. These beds alternate, first with thin bands of black limestone, and are finally succeeded near Llampeter, by large, undulating, calcareous masses, dipping both to the north and south. It is remarkable, however, that the chief inclination is to the north, as seen in the great limestone quarries near Llampeter village. The limestone, dipping 35° to 40° north, is quarried through a thickness of 60 to 70 feet in beds both thick and thin. It is of the usual dark colour, traversed by white veins, has few or no way-boards, and is largely extracted for burning to lime. In the prolongation of these strata through the fertile farm of Langwathan and the valley of the White Mill stream, and also between Llampeter and the southern frontier, the characteristic fossils, including a profusion of the *Asaphus Buchii* and *A. tyrannus*, may be collected. In the loftier subsidiary ridges of Pen-gaer and the Ffron, north of Llandewi Felfrey, these flagstones also contain, at intervals, thick expansions of limestone sufficiently good to be burnt. Here also the dip is generally reversed and unconformable, for as these hills trend from north-east to south-west, the most prominent escarpments face to the south-east, as under Pengaer. On the whole, however, they may be described as undulating or dome-shaped masses, since upon their north-western confines, the older rocks plunge under them, dipping to the south and south-east. They sometimes expose the beds of passage upwards into the Caradoc sandstone, as in nearly horizontal strata at Pen-blowin, a mile and a half north of Narbeth, and at the Ffron, where the calcareous beds are again almost horizontal. Here, though occasionally burnt for lime, they are usually extracted for road and coping-stones. In the principal quarries, the backs of the beds expose a succession of small swallow holes or arched cavities, a feature not often observed in limestone of this age. Fossils are abundant, particularly the *Orthis canalis*, and corals. At Whitley, north-east of Narbeth, where the calcareous ridges of Llandewi and Llampeter unite; the old quarries expose violently contorted strata, dipping both to the north and south, and appearing to rise from beneath the younger formations. From this point in their course to the westward, the Llandeilo flags become gradually less important, for the limestones thin out and the fossils disappear. Their southern frontier or upper member is, however, clearly defined, about half a mile north of Robeston Wathen, where beds of black limestone, two, three, and five feet thick, alternate with dark grey shale, and passing upwards into sandy flags, dip at an angle of 40° under the Caradoc sandstone before mentioned. Fossils at this spot are plentiful, particularly a singular serpuline body, and a new species of coral.

We here perceive that the calcareous matter is thinning out, showing a tendency to run into concretions; and in following the direction of the strata we lose, for a time, all traces of it. The limestone, however, again emerges directly in the western prolongation of these beds at Sholeshook,

about a mile north of Haverfordwest, where on the right bank of the river it was formerly quarried for burning. It is there a bulging concretionary mass, much less pure than at Llampeter and Llandewi, and rises in an arch from beneath the Caradoc sandstone of Prendergast and Haverford. Fossils are apparently much scarcer, though I perceived fine specimens of corals. To the west of Sholeshook we lose all distinct traces of the Llandeilo flags, as marked either by fossils or limestone; but the black schists occasionally passing into flagstones, which are continuous from that place by Crow Hill, Red Hill, and Cutty Bridge, most probably indicate the course of the formation, since at Camrose we again meet with a black limestone, which, though apparently void of organic remains, agrees exactly in mineral characters with the Llandeilo limestone of other parts. Here the whole of the Silurian System gradually bends round from a westerly, to almost a northerly direction, in which strike the calcareous flags and limestones of Camrose dip 40° west, and may, therefore, be supposed to pass beneath the sandy incoherent schist and sandstone, which represent the overlying members of the Lower Silurian Rocks. This gradual attenuation of calcareous matter to the westward in the inland range of the Llandeilo flags, precisely accords with the features in the sea cliffs of St. Bride's Bay, where the formation is seen for the last time containing the true organic remains, but very little lime. (see p. 394.)

## *Cambrian System.*

A tolerably precise base line of the Lower Silurian Rocks may be drawn along the northern flank of the above-mentioned Llandeilo formation, as defined by the calcareous flags and limestone with associated fossils. The next inferior strata, like a large portion of those in Caermarthenshire, are, however, with difficulty separable by their mineral aspect from the overlying beds of the Silurian System, except where certain bands of encrinital sandstone occur similar to those described. (pp. 394 and 395.)

*a.* The upper beds consist of a vast development of black shivery schist, generally void of hard stone bands, with no traces of lime, and with scarcely a vestige of organic remains. In some districts they form more naturally the base of the Silurian System, into which they graduate, but in Caermarthenshire they also pass into true roofing slates; it is therefore preferable to consider them the beds of passage between the two systems. To the north of the escarpment they dip under and pass up into well recognised Llandeilo flags through the medium of certain beds of grey and brown grit, similar to those on the north-western face of Grongar Hill, Caermarthenshire. Owing to their slight and variable inclination, these schistose beds in Pembrokeshire occupy a wide zone between the true Silurian System on the south and the hard Cambrian rocks on the north, but owing to their perishable nature they have been much denuded. Rising to little altitude, and weathering to a stiff clay, they present a cold, barren, agricultural surface, strongly contrasted with the adjacent fertile tracts occupied by the Llandeilo flags. These schists are nowhere exposed in the coast of St. Bride's Bay, being cut off by the trap which ranges from Castle Rock to Trafgarn, and overlapped still further to the west by the coal measures of Newgale Sands and Brawdy.

*b.* The shivery schists are succeeded on the north by courses of hard sandstone, grit, and thick flagstone, all of which agree, more or less, mineralogically with the term "greywacke." Examples of this rock occur at Parkstone quarry, eight miles north of Haverfordwest, where there are hard intractable grits and sandstones, of light grey colour, made up of fragments of quartz, trap, slate,

and other rocks, with much felspar in the base. These beds dip 40° north, while at Trifleton quarries, courses of dark grey, hard, flaglike grits dip 25° south-east, being thrown off the southern flanks of the Trafgarn trap ridge. Similar flagstones are worked at Bwdloi and other places along this line.

*c.* The next practicable division in the Cambrian rocks of Pembrokeshire, consists of hard, dark, purple, grey, and green, close-grained sandstones, with a partially slaty cleavage, and perfectly resembling the rocks of the Longmynd and Linley Hills, Salop[1], and of the Lammermuir hills in Scotland. They are displayed in a long range of sea-coast between Brawdy and the north end of Newgale Sands, where they have been mentioned as environing and abutting against the coal measures and extending thence to St. David's, where they pass into still older slaty rocks. Excellent examples of these party-coloured, finely laminated, hard sandstones are also exposed in the cliffs of Skomer, and will be mentioned in describing the trap rocks of that island.

*d.* The oldest rock in Pembrokeshire is the schist, which rises from beneath the purple and grey sandstones of St. David's, and constitutes those great masses which, having a more decided slaty structure than the strata just described, are worked at intervals for roofing slates. With this schist are associated many courses of hard sandstone passing almost into quartz rock, and traversed by numberless veins of pure quartz, giving to this tract a much more siliceous character, than is possessed by any previously described.

### *Slaty Rocks.*

In the southern end of Whitesand Bay near St. David's, the cliffs expose a succession of hard, dark grey and light green, slaty sandstones, which strike from 10° to 15° north of west. These beds are cut through obliquely, from north-east to south-west, by planes of slaty cleavage (in perfect accordance with the prevailing strike of the slates through Wales), and dip 65° to 70° to the north-west.

At the northern side of the bay, and not half a mile distant, are vertical beds, differing little from the preceding in composition, but without slaty cleavage transverse to the laminæ of deposit. In some of these are large veins of white quartz, the strata undulating with a prevailing strike of E.N.E. To these succeed (in vertical cliffs 150 feet high) masses of slate, which were formerly extracted for roofing purposes[2].

In this instance, the planes of cleavage and stratification are apparently one and the same, the latter being marked by the succession of mineral layers of different colours, frequently separated by very thin laminæ of iron pyrites, and the slates are obtained by splitting the stone along these lines of bedding.

It is, however, well worthy of remark, that these highly inclined beds rise in the form of flagstones, presenting, when *very closely* examined, slightly uneven surfaces,

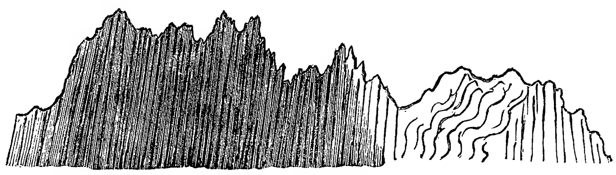
[1] See p. 255 *et seq.*

[2] Since the memoir upon Pembrokeshire was read before the Geological Society, Professor Sedgwick and myself visited the county together. On this last occasion I was called away by a severe domestic misfortune, before I could re-examine Northern Pembroke, so that the portion of the map relating to that tract, has been much improved by my friend's labours alone.

whilst the finer planes *between* their courses of original deposit, split in lines precisely and mathematically parallel, as if they had resulted from a crystalline action, *subsequent* to the deposition of the sediment.

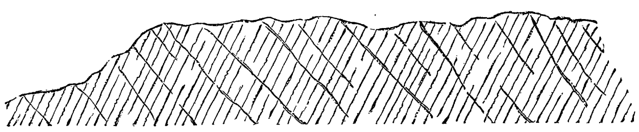
In the above-mentioned quarries, where the lines of stratification are coincident with those of slaty cleavage, the phenomenon is represented in the upper wood-cut, while the discrepancy between cleavage and stratification, as is usually the case, appears in the lower.

80.



Cleavage and beds coincident.

81.



Cleavage and beds divergent.

It does not appear to me, that in the cases of coincidence, the term flagstone can be applied to pure and good roofing slate, merely because the cleavage is not oblique to the lines of bedding.

It is indeed manifest, as first suggested by Mr. Lonsdale, (after the memoir[1] on this subject had been read before the Geological Society) that there must be coincidences between the lines of cleavage and stratification, where the former maintain a fixed position and direction, and the latter undulate in broad curves, as represented in this wood-cut.

82.

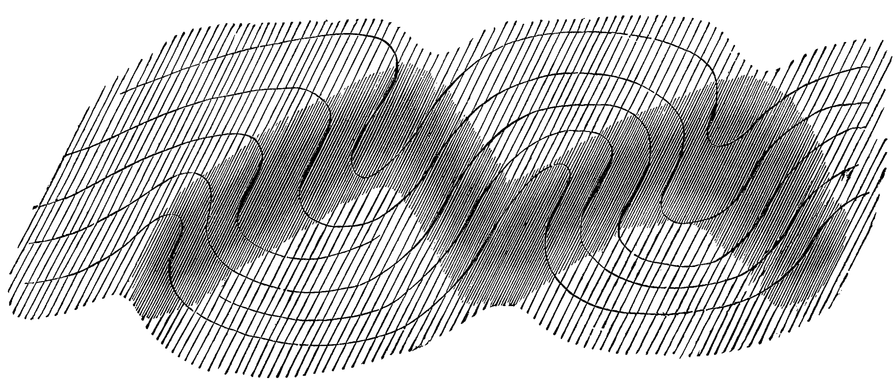


Diagram explaining how in undulatory strata, the cleavage and laminæ of deposit must occasionally coincide. The darker portions of the mass are those where the coincidence occurs.

Examples of both phenomena may be seen in the same range of slate quarries at Panti-philip, a few miles south of Fishguard.

[1] Proceedings of the Geological Society, vol. ii. p. 226 *et seq.* and Phil. Mag. vol. viii. p. 564.

Again, in the principal range of the slate rocks constituting the Precelly Mountain, where the greatest quantity of the best slate is obtained, there are occasional coincidences of cleavage lines and laminæ of deposit. The same phenomenon has since, indeed, been observed by Professor Sedgwick, both in this range, and also along the line of coast cliff on the sides of Abereiddy Bay, where, if there had been any doubts upon the question, they would have been entirely dispelled, as fossil bodies (Graptolites), occur upon the *lines of slaty* cleavage, which are thereby proved to be coincident with *true layers of deposit.*

Thus, this important modification of the principle of slaty cleavage, which I pointed out to the Geological Society in 1835, has received the full and entire sanction of Professor Sedgwick. The above-mentioned cases are, however, to be distinctly understood as marked exceptions to the prevailing phenomena in Wales.

The chief objects which I had in view in examining North Pembroke were, 1st. The succession of the strata between the Silurian System and roofing slates of Precelly. 2ndly. The direction in which the principal masses were prolonged to the sea-coast. The former has been explained; to the latter point, after a short description of the trap rocks, I shall specially invite attention.

### *On the Trap Rocks of Pembrokeshire.*

Pembrokeshire offers many examples of the two classes of trap rock which have been described in other tracts, viz. stratified masses alternating with sedimentary deposits, and amorphous masses which have burst through the strata. The former or stratified traps are, however, nowhere seen in association with the Silurian rocks, as in Salop and Radnor, but are confined to the Cambrian or older system. In the rugged and arid headlands north-west of Fishguard, noted in modern times for the landing of a small French force, linear parallel ridges of trap occupy a very large portion of the tract, rising in gnarled bosses through altered sandstone and slate. They strike from north-east to south-west along the craggy summits of Gaer-fawr and terminate in St. David's Head.

Among these older trap rocks are thick-bedded coarse felspathic conglomerates, containing fragments of schist and slate, which range from north-east to south-west in allinement with the other ridges of amorphous trap. Some, however, of the more prominent of these parallel ridges, between St. David's and the headlands north-west of Fishguard, appear rather to belong to the class of intrusive trap, and they generally inclose between them, highly altered greywacke and slaty rocks. They consist of greenstones of several varieties, passing into porphyritic greenstone and porphyry, together with much compact felspar rock ("corneen"). It is, however, difficult to define all these masses in such a manner as to separate those which are of formation contemporaneous with the slates from those which have been subsequently intruded.

The mineral composition of the rocks near St. David's has been somewhat minutely described

by Dr. Kidd (Geol. Trans., Old Series, vol. ii. p. 79.), and they have also been alluded to by Mr. De la Beche. Among them, however, is a variety which appears to have escaped the notice of these authors. It is a highly crystalline, large-grained greenstone, made up of albite, mixed with minute dark crystals of chromate of iron. The rock also contains some quartz and the oxides of iron and of chrome, and an earthy mineral substance which may be decomposed augite[1]. The compact felspar rocks are frequently coloured green by a diffusion of epidote or chlorite.

Some remarkable examples of the most completely altered rocks, such as flinty schist passing into flint, are in the stony ridges to the west of Goodic Sands. Most of the irregular masses of trap along the north side of St. Bride's Bay, between St. David's and the coal-field, have been mapped and described by Mr. De la Beche, who has also marked trap rocks as occupying the Island of Ramsey with most of the adjacent islets (Bishop and his Clerks, &c.)[2].

One of the most striking of the trap ridges of Pembrokeshire is that of Trafgarn, which trends from Roche Castle near the coast, in a zig-zag form and a north-easterly direction to Trafgarn, where it bifurcates and is continued to the north-east in two great bands, which terminate in Wallis Common and the rugged tors of Ambleston. At Roche Castle and at Trafgarn the rock is a mass of compact felspar, quite undistinguishable from that of the Wrekin and many rocks previously described. At Ambleston it becomes a porphyry and porphyritic greenstone, &c. The intrusion of this rock has produced a powerful effect upon the adjacent strata, particularly on those masses inclosed between the forks of trap in the gorge of the river at Trafgarn, where the red and green sandstones are converted into a brittle, siliceous substance, resembling the ribbon-jasper of mineralogists. It is largely used as a wall and building stone. Though offering no traces of true bedding, the compact felspar of Trafgarn is divided into rude prisms by two sets of planes or vertical and horizontal joints, giving rise to square-topped masses like ruins, which stand out in bold contrast to the prevailing outline of the county, somewhat like the serrated quartz rocks of the Stiper Stones in Salop. This range of trap, as well as a thinner band of porphyry, lying to the north of it and crossing the river at Scillyham, appear to be intrusive; and rocks of the same character re-occur at various points along the higher slaty chain, even to the eastern extremity of Precelly. Without dwelling, however, upon this north-eastern district, to which I gave comparatively little attention, let us now consider the trap rocks to the south of Haverfordwest, where they are intimately associated with the Silurian and younger stratified deposits,—the special objects of my research[3].

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[1] It is upon the authority of Professor Miller of Cambridge, who examined the specimens, that this mineralogical statement is made.

[2] Since that author wrote, small veins of copper have been observed in the altered rocks near Solfach, adjacent to certain trap rocks. There are also two copper veins running across the promontory of Pen-maen near St. David's, from S.S.E. to N.N.W., and these are flanked on the east by a *most remarkable quartz vein, twelve yards thick.*

[3] In reference to the points and lines of trap between Precelly and Newport, it is by no means contended that North Pembroke is so accurately worked out, that future observers may not add much to our knowledge. Through great portions of this tract the alternations of trap are so very frequent, that it is almost impracticable to lay them down upon a map of the scale which I have adopted.

*Ridges of Johnston and Benton Castle.*

These masses of trap are both of intrusive character. They were previously thought to be continuous from the hills north of Johnston to Benton Castle, but they are in fact separated by a band of Silurian rocks. As a continuous mass, the trap of the Johnston ridge has a length of about six miles, from Nash to Tier's Cross, cutting from east and by south to west and by north, through the carboniferous strata on its northern flank, and throwing off the Lower Silurian Rocks to the south. Though rising to the highest land in this division of the county (Bolton Beacon), this trap ridge is nowhere diversified with rocky tors like those of Trafgarn and the northern parts of Pembrokeshire, but forms round-backed sloping hills, a feature chiefly due to the disintegrating nature of the rock. Thus at Nash and Clarisson the greenstone weathers to yellow incoherent sand and gravel, which in some cases are cut through to a considerable depth before the body of hard rock is reached. At Johnston, the greenstone is so quartzose, that by some geologists it has been called syenite, and at Bolton Beacon it passes into true greenstone and porphyritic greenstone. The line of eruption is marked at intervals to the west of Bolton Beacon, as at Walwin's Castle (where there is a dyke of compact felspar), till it reappears in great force in the sea cliffs of Gouldtrop road, where Mr. De la Beche has described it as a large and fine-grained greenstone passing into syenite. He further points out that although this rock does not differ in mineral composition from those associated with much older strata, yet that it traverses equally Old Red Sandstone and coal measures, the latter being bent back at the points of contact, and one large fragment of the carboniferous limestone being actually twisted into the mass of trap. Hence he justly inferred, that it was impracticable to draw geological distinctions between the then so-called greywacke or transition trap and the rocks of similar composition which burst through the younger strata. I have previously alluded to a spur or dyke of this rock which, to the north of Newgale sands, disturbs the coal measures and the Cambrian System; and in Marloes Bay the Silurian rocks have been subject to a similar intrusion. South-west of the Johnston ridge, at the farm-house of Roman's Castle, a small insulated point of trap bursts up through the Lower Silurian Rocks, throwing off altered and contorted strata; and directly to the west of this dyke, a similar rock protrudes through the Old Red Sandstone near Little Hasguard.

*Benton Castle Trap.*

This mass has a length of nearly four miles from Benton Castle to a point north-west of Rosemarket. It ranges from W.N.W. to E.S.E. In Rosemarket Common it is a sort of trap tuf, enveloping fragments of quartz and hornstone; and this rock, passing into compact felspar, protrudes through altered Silurian sandstone between Rosemarket and Waterless. These felspar rocks, graduating into porphyry, occupy the high grounds of Hearston Common and run out to a narrow point on which Benton Castle stands, on the right bank of the Haverford river, where they throw off unequivocal Old Red Sandstone on the north, and are flanked on the south by a very narrow stripe of decomposing yellow shale and sand, which in the absence of fossils it is difficult to refer. This zone of trap does not strictly terminate at Benton Castle, but crosses the river, protruding into and dislocating the Old Red Sandstone, and enveloping fragments of that rock. In its final appearance in the cliffs it is a conglomerate tuf, like that at the other extremity near Rosemarket, but in this instance the included quartz pebbles predominate so very much over the felspathic base, that in

hand specimens it could not be distinguished from many sedimentary rocks. It performs, however, most clearly the part of an intrusive rock, since it has not only flowed in one part in bulging irregular streams over dislocated and angular portions of sandstone, but also throws up other strata of sandstone into a vertical position, which in contact with the trap conglomerate are almost in the state of quartz rock as represented in this wood-cut.

83.


Fault.

*a.* Old Red Sandstone. *a**. Altered Old Red. *b.* Trap conglomerate.

The direction impressed upon the associated strata by the eruption of this band of trap, is well exposed in the cliffs, a few yards south of the trappean conglomerate, the Old Red Sandstone having a strike from E.S.E. to W.N.W.

The surface or agricultural character of these ridges of trap of Johnston and Benton Castle consists for the most part of absorbent, sandy soils, and where the greenstone is much decomposed, they resemble those sandy and gritty tracts in France derived from what Dolomieu termed "Granite pourri."

### *Trap of Skomer Island and Marloes.*

No part of Pembrokeshire, which fell under my notice, offers such clear examples of both the stratified and unstratified trap rocks, as the Island of Skomer and the adjacent promontories of the mainland, which form the western end of Broad Sound. When viewed from a distance, the outline of Skomer is most remarkable, presenting a number of steps or ledges, which unlike the prevailing forms of trap are not horizontal, but inclined at angles of 35° and 40° to the S.S.E., thus appearing to dip in conformable stratification beneath the Silurian System of Marloes Bay. (See vignettes, p. 389 and 392[1].)

When closely inspected, these stratified masses are found to consist of purely crystalline greenstone, dark green, granular felspar rock, and felspar breccia or conglomerate, which alternate conformably in thick, parallel masses, with regularly stratified, purple, green, and yellow sandstone and schist of the Upper Cambrian System. Such alternations are displayed in North, South, and Wick Havens, in each of which the powerful currents of the sea, which set in at these extreme points, have worn the softer portions of the rock into coves, the only spots along the rugged coasts of the island where a boat can land. The stratified masses of greenstone and felspar conglomerate are so numerous, and alternate so equably and frequently with sandstone and schist, that I consider they must have been evolved at intervals from volcanic fissures at the bottom of the sea, during the accumulation of the sand, pebbles, and mud, with which they are associated, and into which there are occasionally such close passages, that it is most difficult to say where the trap rock terminates. For further description of similar contemporaneous trap rocks, and for explanations of the mode in which they have been formed beneath the sea, the reader is referred to chapters 5, 19, 22,

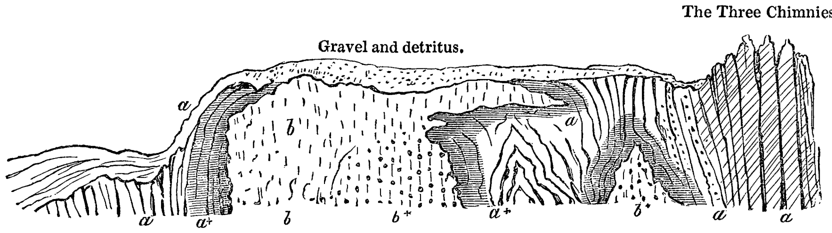
[1] Both these wood-cuts are taken from sketches by Mr. Francis Leach.

23 and 26. These stratified masses of trap and greywacke are usually rent by faults and fissures, in the proximity of the large amorphous masses of unstratified and amorphous trap.

The intrusive trap cuts in vertical dykes through the bedded trap and sandstone, and rising into the chief hills of the north-west of Skomer, also protrudes in irregular masses south of North Haven, in Midland Isle, and both sides of Jack's Sound. Occupying the extremities of the mainland, called the Hay's Point, Tufker Rock, and the Anvil, the same amorphous trap ranges along the coast to the east by Hook Farm to Marloes Village, occupying two or three low tors within the promontory. These rocks, which in this vicinity cut through all the deposits, from the Cambrian to the Old Red System, including the Silurian strata, consist of highly crystalline greenstone of various characters, some slightly porphyritic, and of compact felspar rock in great abundance, the latter (as near the Hay's Point) being occasionally coated over with films of serpentine. This trap not only contorts and dislocates the sandstone and schist with which it is in contact, but, as in numberless other cases, converts the former into granular quartz rock, of which a good example may be seen at Martin's Haven. In this tract, while the stratified and alternating trap strikes from E.N.E. to W.S.W., in conformity with the direction of the Cambrian and Silurian Systems; the intrusive trap bursts out at irregular points, traversing the above obliquely, or from east and by south, to west and by north.

This is clearly exemplified in the ridge of porphyritic greenstone, extending from Marloes to Martin's Haven; and even where this rock appears in small or detached points, it is accompanied by similar phenomena. The most striking example, perhaps, is where the little boss before alluded to, p. 393, juts through the Upper Silurian Rocks in Marloes Bay, as represented in this wood-cut. (See Map.)

84.




*a*. Strata of Sandstone, Shale. *a**. Strata of Sandstone, Shale, altered in contact with Trap.
*b*. Greenstone and Amygdaloid, &c. *b**. Trap Conglomerate.

The trap is there a crystalline greenstone, passing into a purple amygdaloid, with kernels of green earth and veins of epidote, in a base of compact felspar. On the south side, it graduates into an amorphous trap conglomerate, having a matrix of compact felspar with included pebbles of quartz, some as large as a child's head. This mass bulges out under twisted and altered strata of sandstone, whilst the chief body of the crystalline trap, rises nearly to the top of the cliff (here about 150 feet high) and partially overflows the ends of the beds, which are bent back and contorted, *their strike being changed from that of W.S.W. E.N.E., which prevails throughout Marloes Bay, to west and by north, east and by south.*

We thus see, that in South Pembroke, whether at Benton Castle or in Marloes Bay,

where trap dislocates the strata, the points of intrusion are accompanied by conglomerates and altered rocks, both resulting, doubtless, from great disturbance of the pre-existing formations.

These facts, particularly those which indicate the change of direction of the strata, naturally lead us to consider the epochs when the eruptions took place.

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### *Conflicting directions of the strata in Pembrokeshire caused by divergent eruptions of Trap.*

No geologist can examine Pembrokeshire without perceiving, that its stratified masses are the theatre of two great divergent lines of *strike*. One of these, proceeding from north-east to south-west, with slight variations towards the east and west, is the same which has been followed from Shropshire and Montgomeryshire to the sea cliffs of St. David's. The other, trending from east and by south, to west and by north, maintains its direction through South Pembroke, with the exception pointed out in Marloes Bay and Skomer Island. An inspection of the map indicates the extent of country affected by these divergent strikes. The first was impressed upon the strata during the accumulation of the Cambrian and Silurian Systems, and the causes which gave rise to it, continued in operation during the deposit of some of the subsequent formations. The second was the result of violent movements which took place suddenly, and posterior to the solidification of the carboniferous system.

These inferences are fully substantiated by facts. In North Pembroke we have cited many examples of parallel bands of trap *interstratified* with the beds of sediment, showing that igneous agency was in activity during long periods; while ridges of *intrusive* trap have been pointed out in that district, which have burst through the same strata at a later date, but upon the *same* parallels. In short, these two classes of volcanic matter in North Pembroke, whether contemporaneous or posterior, have been emitted upon lines trending from north-east to south-west, or E.N.E. and W.S.W. Such results are precisely analogous to phenomena which have been described in Salop, Montgomery, and Radnor; and there can be no doubt, therefore, that not only the bedded trap, but also the amorphous masses in the slates of North Pembroke (such as Trafgarn, Caerningley, &c.) were erupted anterior to the accumulation of the carboniferous system, and upon pre-existing habitual lines of eruption.

In Shropshire it has been shown, that volcanic eruptions from north-east to south-west were again in activity after the formation of the Carboniferous and New Red Systems. Not so, however, in Pembrokeshire. Here, on the contrary, the carboniferous rocks have a direction from east and by south, to west and by north, thus forming an angle of at least 45° with the average axis of the older rocks. As the north-

east and south-west direction of the latter is abundantly explained by the linear and parallel masses of trap; so is the carboniferous axis of South Pembroke satisfactorily accounted for, by the trappean ridges extending from Benton Castle on the east and by south to Talbenny Cliffs on the west and by north. Thus, in both these tracts the divergences of direction of the strata are distinctly referable to separate linear eruptions.

Volcanic or eruptive forces, sufficient to determine the east and by south, and west and by north allinement of South Pembroke, could not have taken place in a large mass of matter, most if not all of which had previously a north-east and south-west direction, without subjecting it to prodigious rents and dislocations. Many of these fractures have been pointed out in describing Caermarthenshire, where it has been shown, that Silurian and slaty rocks, previously consolidated, have been snapped across by subsequent movements, which, wrenching them from their original direction, have thrown them into the axis of the Glamorganshire coal basin: but none of the fractures coincident with that axis, either in Glamorganshire or in Pembrokeshire, are accompanied by outbursts of volcanic matter. It is therefore highly satisfactory, in following the strata so affected into Pembrokeshire, to find them pierced by trap ridges, having precisely the same course as the major axis of the South Welsh coal-field.

The interference of two such lines of elevation also explains the contortions and breaks of the carboniferous strata; since it is evident, that shale, sandstone, and limestone, when compressed between these lines of powerful movement, must have been subjected to extraordinary contortion and dislocation; while the seams of frangible anthracite would be so shivered into numberless small fragments, as to form the slashes of culm which are characteristic of Pembrokeshire.

A thorough examination of this region may well excite deep interest, not only in bringing to light the numberless proofs of the violent disturbance resulting from the interference of this great east and west movement with the ancient direction of the strata, but also in showing over how great a breadth of surface its effects extended. Thus, besides the zone specially affected in the southern part of Caermarthen and Pembroke, the width of which is from eleven to fifteen miles, the east and west strike has been also impressed upon the strata, *at intervals*, very far to the north, extending along the boundary between Pembrokeshire and Cardiganshire. Examples of it have been cited in the slaty rocks of St. David's, Scillyham, and Abereiddy. Another striking case is south of a spot called Felindre, where the Nevern stream descends from the Precelly ridge to the valley of Newport. The strata on its west bank, have the prevailing strike of the region from north-east to south-west, and parallel to the great trap ridge of Caerningly, while on the east bank, the same strata are broken off, ranging east and west[1]. Similar oscillations between these conflicting directions, are seen as far north

[1] The dislocation at Felindre was observed by Professor Sedgwick.

as Newcastle Emlyn, the river Cothi running in similar breaks of the strata, some of which strike east and west; but these are rare exceptions to the prevalent south-westerly direction of that slaty region. (See Map.)

Let those who are incredulous as to the intensity of the forces employed in producing the disruption and contortion of the ancient strata, examine for themselves the tract between the valley of the Towy on the east, and the coast cliffs of Pembrokeshire on the west, and I have little doubt that, whatever may have been their preconceived theory, they will come away convinced, that such phenomena could have resulted only, from action of much greater power than any which has been in operation during the historic æra.

To what extent the evidences here adduced may sustain some of the views of M. Elie de Beaumont, in respect to the age of these directions, will be considered, when all the phenomena bearing upon this subject in other tracts (Hereford, Worcester, Stafford, Gloucester, &c.) have been described. I will then endeavour to generalize the application of these data, though in the meantime I may observe, that the east and west strike of South Pembroke is not a mere local phenomenon; since it forms the major axis of the South Welsh coal basin, and the tract affected by it is nearly one hundred miles in length. (See Map.)

*Part of the Malvern Hills as seen on their western flank, from a sketch by Mrs. Murchison.*

# CHAPTER XXXI.

## MALVERN AND ABBERLEY HILLS.

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*Silurian System in Worcestershire and the Eastern part of Herefordshire. Syenite and other Trap Rocks of the Malvern and Abberley Hills, and dislocations of the Silurian System along their flanks.* (Pl. 36, figs. 1 to 8.)

*Course and Characters of the Silurian Rocks on the Eastern side of Herefordshire.*

IT has been stated that the Old Red Sandstone of Herefordshire was deposited in a trough. To establish this position I proceed to show, that rocks similar to those on which it rests in Shropshire, West Hereford, and South Wales, rise from beneath the eastern side of the chief mass of Old Red Sandstone.

The Silurian rocks, though occupying a narrower zone than in Shropshire, constitute an almost continuous band from the northern end of the Abberley Hills to the southern end of the Malverns, a distance of nearly twenty-four miles, and though the strata are dislocated, and even, through a course of four miles, *reversed*, yet they maintain a prevalent inclination to the west, dipping beneath the Old Red Sandstone. Emerging through these Silurian deposits, and forming a buttress on their eastern flank, are certain igneous rocks, which in the Abberley Hills protrude only at intervals through the dislocated strata, but in the Malvern Hills constitute a narrow ridge of syenite, rising

to some height above the Silurian deposits as represented in the above vignette. The altered characters and dislocations of the strata, produced on the sides of these trappean hills, will be noticed, after the nature of the intruding rocks has been described; observation being first restricted to the nature and range of the sedimentary deposits of the Silurian System.

### *Ludlow Rocks in the Abberley Hills.* (Pl. 36, figs. 1 to 4 inclusive.)

*Ludlow Rocks in the Abberley Hills.*—This upper formation of the Silurian System occupies about one mile of the ridge immediately to the east of the village of Abberley, marked Abberley Hill on the ordnance map. It is cut off upon the south by intrusive rocks, which, forming a knot of still higher elevation, extend about three quarters of a mile to the west, encircling and overhanging the village of Abberley on the one side, and receding from the Hundred House on the other. Beyond, and to the west of this trap, the Ludlow formation is thrown off in very contorted and dislocated masses, constituting a headland which advances into the coal field of Abberley and Pensax. From the western side however, of Abberley Lodge, the formation rises into a distinct mural ridge striking S. 10° W. along the western side of Woodbury Hill; to the south of which it takes a direction a few degrees east of south to Hill End near Martley, the beds disappearing at Kingswood Common. Thence to the gorge where the Teme is deflected through this band, the Ludlow rocks are no longer traceable, older Silurian deposits forming the narrow ridge which separate the Old Red Sandstone on the west, from the New Red on the east. Throughout its course on the western slopes of the Abberley Hills, the Ludlow formation offers, on a small scale, the same triple subdivision as in Shropshire. The upper part, or true Ludlow rock, is the same argillaceous thin-bedded sandstone, containing the gigantic *Serpuloides*? *longissima*, *Leptæna lata*, *Cypricardia amygdalina*, and other characteristic fossils.

The Aymestry limestone, or central member of the Ludlow formation, is also well defined, and in parts nearly as thick, but never so pure as in Shropshire. Although it has been burnt for lime from the crest of the ridge east of Abberley; the rock is now only extracted for the roads, the adjacent limestone of the Wenlock formation being of very superior quality. The fossils of this rock are nearly all the same which are found in it in Shropshire, with the exception of the *Pentamerus Knightii*, which I have not detected. The large *Lingula Lewisii* is perhaps the most striking of the organic remains, often retaining, in great perfection, its thin shelly matter. The lower Ludlow rock is also recognised by containing many of the same organic remains as in Shropshire. (See List.)

From the decomposing nature of the sandstone and shale beds, they are locally called "Mud Stone," in contradistinction to the hard trappean rocks which occasionally protrude, and are termed "Jew Stone," as in the Clee Hills. The total thickness of the Ludlow formation in the Abberley range does not exceed 300 feet.

### *Ludlow Rocks of the Malvern Hills.*

The Ludlow formation is clearly displayed in a number of low and generally wooded eminences, on the western flanks of the Malvern Hills, from which it is separated, in some parts, by the

Wenlock limestone, in others by a third ridge formed by the Caradoc sandstone. (See vignette.) With the exception of certain breaks and flexures, for a knowledge of which the map must be consulted, the Ludlow formation ranges from north to south, passing from Suckley Hill by Berrow Mill, Hales End, Hill Houses, High Grove to Mathon Lodge, on the western side of which it is thrown by undulations into two parallel ridges. (Pl. 36. f. 7.) Thence by Brockhill Copse to Evendine Street, it occupies only one zone. At Chance's Pitch and Dawes Castle, it is deflected from the Malvern chain, and is split into three parallel lines, having a strike from N.N.W. to S.S.E.: the hills extending from Combe Hill to Dogberry Pools, north of Ledbury, mark the outermost of these lines. At Ledbury (a point of dislocation and great flexure), the formation is suddenly twisted from the direction of the Wenlock limestone which there takes its place, being changed from N.E. and S.W., to N. and S. Throughout their course on the western side of the Malvern Hills, these Ludlow rocks preserve all their Salopian mineral distinctions, and nearly all the fossils, (see p. 197 *et seq.*), with the exception of the *Pentamerus Knightii,* which is wanting in the central or calcareous part, representing the Aymestry limestone. The quarries at Langley Green, Hale's End Wood, Evendine Street, Chance's Pitch, are perhaps the best localities for fossils; particularly that of Hale's End, where the equivalent of the Aymestry limestone is very well displayed. The upper Ludlow rock repeatedly passes at various degrees of inclination beneath the Old Red Sandstone, and the lower Ludlow shale or mudstone is as uniformly incumbent on the Wenlock limestone. In general, the upper Ludlow rock is better developed than the lower, particularly along the edge of the Old Red Sandstone, but the latter is equally well exhibited at certain points, (Evendine Street, in the deep lanes and water-courses between Brockhill and Colwall Coppices). As in Salop and West Hereford, the upper rock, including the calcareous band representing the Aymestry limestone, is a harder stone, and hence it constitutes the ridges, whilst the lower, a true *mudstone,* has been scooped into longitudinal valleys parallel to the ridges. (Pl. 36. figs. 6, 7 & 8.) In the shale beds which pass down into the Wenlock limestone, we find occasional concretions of impure limestone[1].

The Ludlow rocks on the side of the High Road at Chance's Pitch, between Malvern and Ledbury, are very instructive, and present clear examples of the same jointed structure as in Shropshire. At Ledbury, and thence for a short distance through the park of Mr. Biddulph, the whole of the Ludlow formation, so fully laid open in the above-mentioned localities, is reduced to a narrow band of thin-bedded yellowish sandstone, which from its position at the Dog Hill seems to be the equivalent of the Downton Castle building-stone, p. 197. This rock being for the most part in a very broken and partially altered condition, is of slight lithological value. It is vertical at the Dog Hill, and in Ledbury Park is thrown over into an unconformable position by a reversed dip, as explained in Pl. 36, f. 8.

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[1] The mania of boring for coal through these ancient rocks, of which many other examples are cited in this work, has unfortunately affected some of the inhabitants of this tract. At Mathon Lodge, anno 1832, I found open shafts, which had been sunk to a depth of about 120 *yards* in the Lower Ludlow Rock, at a point marked in the section, (Pl. 36, f. 7.), where it ought to have been apparent to any one however ignorant of geological phenomena that the limestone of the adjacent ridge of Croft Farm and Castle Copse, must, by its inclination, be carried beneath this very shale. This, as well as the other absurd trials in the incoherent shale of the "Silurian System," wherever it happens to be *black,* has been caused entirely by the lithological and mineral characters of the rock, which in truth does not differ very materially to an unpractised eye from the shales of the coal-measures. (See observations p. 328 *et seq.*, on the coal speculations in Radnorshire, and on the similarity between certain coal shales and the rocks of this age in Pembrokeshire, p. 374 *et seq.*

The same rock reappears in Dunbridge Wood, where it contains casts of fossils, though the prevailing feature along this frontier of the Silurian rocks south of Ledbury, is, that the Wenlock limestone is brought directly into contact with the edge of the Old Red Sandstone, the Ludlow formation being entirely omitted.

### *Wenlock Limestone and Shale, Abberley Hills.*

A reference to the map will show, that this formation is remarkably broken and disjointed in its course along the Abberley and Malvern Hills. Near the northern termination of the former, the calcareous or uppermost beds occupy a knoll called the "round hill," where excavations have been made to the depth of forty feet, amid arched and contorted beds of greyish blue limestone. This rock occupying a dome, low in relation to the Ludlow formation, is flanked by the New Red Sandstone on the east, and by detritus of Old Red Sandstone and Ludlow rocks on the north. From this knoll, the Wenlock limestone is not traceable on the eastern flanks of the Abberley Hills, to the point where the high road from Worcester to Ludlow crosses the ridge, a little above the Hundred House, where there is a splendid exhibition of it in vertical strata, which having been followed for some distance by cutting open galleries, the nature and amount of the breaks and curvatures are well exposed. (See Map.) From this spot the limestone is again lost for about two miles, i. e., on the eastern side of Walsgrove Hill, where the elevated hollow between that hill and the trap of Woodbury is filled with broken patches of coal-measures. From the south-eastern shoulder of Woodbury Hill, however, the limestone again occupies a distinct, though low ridge, separated from the Ludlow formation by a valley, and terminating abruptly in its prolongation to the south, in the Hill End lime works. It is in this portion of the ridge that the inclination of the strata has been completely reversed—a phenomenon which will be subsequently explained. In this district, some of the varieties of the limestone are of a reddish colour, but the prevailing tint is the bluish-grey, so prevalent in other districts. From Hill End to Knightwick Bridge, upon the Teme, the limestone is not visible. The shale is ill developed throughout this portion of the range, though traces of it are noticed here and there beneath the limestone, and also in one or two spots on the western acclivity of the ridge between Martley and Ankerdine Hills.

Vast numbers of the characteristic fossils of the formation are found in the various lime-quarries; especially in that of Abberley Lodge, on the south side of the house of Colonel Bromley.

### *Wenlock Limestone of the Malvern Hills.*

In reference to the Malvern Hills, this formation begins to rise about half a mile south of the transverse gorge of the river Teme; whence, though broken by many transverse faults, it is traceable to Clencher's Mill, south of Eastnor Park, a distance of nearly fourteen miles. In the first five miles, the limestone, though subject to a variety of breaks and flexures, to be afterwards explained, has a general direction from N.N.W. to S.S.E. Thence it strikes due N. and S.; but after being violently convulsed on the flank of the syenite of the Malvern range, it is thrown out to the westward in a parallel ridge in the neighbourhood of Ledbury, conformably to the Ludlow rock, and runs from N.N.E. to S.S.W. At Ledbury, however, the southerly direction is resumed, and continues to Clencher's Mill. At the former place, the limestone rises in dome-shaped masses of unequal extent, one of which folds under the lower Ludlow rock of the Dog Hill, as represented

in Pl. 36. f. 8. Another is in the high ground E.S.E. of the town: indeed the Coneygree Wood may be considered as one great dome in which there are several minor flexures, so that thence to the southern termination of the Silurian group, this formation juts out in broken masses in the woodlands, ranging from Ledbury Park to Clencher's Mill, being in its western and southern faces for the most part in abrupt contact with the clays of the Old Red Sandstone, the Ludlow rock for several miles having been entirely suppressed. On the eastern side, however, of Coneygree Wood, the limestone is clearly overlaid by the lower Ludlow rock, which thus occupies a trough, of which Eastnor Hill is the highest part, between the dome of Coneygree Wood and the ridge of the same limestone in Eastnor Park. (See Pl. 36, f. 8.)

The lithological characters of this formation are similar to those which it assumes at Wenlock, Dudley, and many other places. It very rarely contains any of the large concretions or ball stones so common at Wenlock, Walsall, and Dudley, but is loaded with the usual number of small concretions, which occupy lines in the dull-grey argillaceous shale, and alternate with beds of solid limestone. The former, occupying the bands between the latter, are here known under the name of *bumbles*. The massive limestone is quarried along several parts of the range in three distinct tiers, of very unequal thicknesses in the different quarries, and occasionally thinning out or uniting. The thickest masses being about ten to fifteen feet, are divided into various beds, some of which are so crystalline as to be capable of fine polish, and are used for ornamental purposes. At Ledbury, two beds of this rock, together about eighteen inches thick, are termed *Ledbury marble*. At one of the principal quarries near this place, the limestone which is extracted occurs in the following descending order.

| | Ft. | In. |
|---|---|---|
| *Bumbles* or Concretions, with some shale, (good lime) | 20 | 0 |
| Plain Lime | 1 | 3 |
| Thick Lime | 2 | 3 |
| Shattered Lime | 1 | 2 |
| "Grey's" (Ledbury Marble) | 0 | 9 |
| Shattered Lime | 1 | 3 |
| Tough Lime | 1 | 0 |
| "Grey's" (Ledbury Marble) | 0 | 9 |
| Green Lime | 1 | 3 |
| Bottom blue Limestone | 0 | 9 |
| Underlaid by *Bumbles*, as above. | 30 | 2 |

The prevailing colour is bluish and dark grey veined with white; there are occasionally pink veins of calcareous spar, and at Clencher's Mill whole beds are red.

Sections at this latter spot expose

1. Upper shale of red, green, and purple colours, with small concretions. 2. Thin layers of reddish brown limestone, with dividing courses of yellow and purple shale. 3. Strong beds of sub-crystalline limestone, deep red on the exterior, (resembling some of the carboniferous limestone of Bristol), but occasionally yellowish, with dark-green blotches. This stratum contains *Crinoidea*, *Productus depressus*, *Asaphus caudatus*, and other well known fossils of the Wenlock formation. 4. Purple and green shale.

These lithological characters, exceptions to the usual structure, are similar to those at Easthope in Shropshire, (see p. 210.), except in the absence of the very large concretions or ballstones; and it may also be mentioned that some of the beds yield dark, and others light-coloured lime; the black and white limestones of the workmen. I have observed no simple minerals worthy of

notice, except occasional crystals of iron pyrites, very rarely a little heavy spar, and nests of anthracite in small cavities.

Organic remains are nowhere more abundant in the Wenlock formation than in this range, including all the characteristic species of shells, trilobites, and corals, p. 214. When indeed we look at the number of beautiful figures in the plates, taken from specimens found on the western slopes of the Malvern Hills and at Ledbury, we must suppose these localities to be the most favoured in the variety and number of fossils. By far the greater part of these choice specimens have been collected by Mr. Benjamin Bright[1] in the quarries upon the estate of his father at Brand Lodge, and I have, therefore, no doubt, that if collectors as assiduous and enlightened as Mr. Bright, were spread over other districts where the formation appears, the harvest would be equally rich[2].

The Wenlock shale bears the same relations to the limestone, which the Lower does to the Upper Ludlow rock, occupying longitudinal valleys beneath an escarpment. It is marked in the upper part by numerous layers of small argillo-calcareous concretions, but in the central and lower parts, these disappear, and with them the characteristic fossils. Towards the base, bands of sandy impure limestone are observable as in Shropshire, but as these beds rise in separate ridges from beneath the valleys occupied by the shale, they here, as in Salop, indicate a passage into, and are classed with, the Caradoc sandstone.

Although the Wenlock formation is much more largely developed in the west of the Malvern Hills than in the Abberley Hills, it is difficult to assign a precise thickness to the whole. The upper portion, containing the solid limestone, may indeed be measured at many points, and including the *bumbles* may have a maximum thickness of about 300 feet; though if examined at the extremities of its course near Knightwick, it forms only one thin band. The underlying shale occupying as it does when fully expanded, valleys of about half a mile in width, wherein the strata are inclined at high angles, cannot be estimated at less than 600 or 700 feet, which would give a total thickness for the Wenlock formation in this tract of 900 or 1000 feet.

## *Caradoc Sandstone.*

The uppermost band of the Caradoc sandstone is calcareous, sometimes so much so, as to constitute an impure limestone like that of the Hollies in Salop, p. 217. It is not found in the lowest part of the valleys, but usually upon the face of the underlying sandstone, as at various points from Alfrick Pound on the N.N.W., to End Hill near Malvern on the S.S.E., from whence to the Herefordshire Beacon, it is in great measure cut off by the syenite, and subjected to many flexures and breaks, particularly near Mathon Lodge. It is again brought out to the west of Eastnor Obelisk, where it consists of strong, dark-blue, calcareous flags, in beds from two to seven inches

[1] Mr. Ormus Biddulph has also a small collection of the fossils of the Wenlock limestone at Ledbury Park. (See description of organic remains.)

[2] Since my first visits to the Malvern Hills, the city of Worcester has done honour to itself in establishing a Natural History Society. An elegant and commodious building has been erected, the Museum of which, when I last saw it, promised to be soon filled with all the characteristic Silurian fossils.

thick. Much encrinital shale is also associated with the flags quite similar to that of Cowley Park Wood, Alfric Pound, &c. The calcareous and hard flagstone beds were cut to about fifteen feet in depth for the construction of the Park Wall at Eastnor. The rifts and veins are filled with pink calcareous spar, and the flags are usually split transversely into irregular squares like the surface of a chess-board. The flaglike arrangement of these beds, and the absence of concretions, places them in striking contrast to those of the Wenlock formation. The fossils which mark this upper member of the Caradoc formation at Stump's Wood in Eastnor Park, consist of three species of *Orthocera*, *Pentamerus lævis*, *Lingula lata*, &c. the two last-mentioned fossils occurring in the same zone near Buildwas, and at the Hollies in Shropshire.

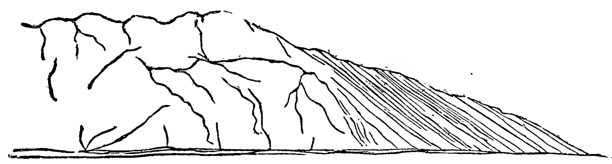
The sandy or central mass of the formation is seen at the southern termination of the Martley Hills, rising into the still loftier Hill of Ankerdine, the highly inclined strata of which dip both to the west and east, with the exception of a slight trace of the bottom of the overlying group of Wenlock shale. On its north-western face this rock constitutes the only division between the Old Red Sandstone of Hereford, and the New Red of Worcester. (Pl. 29. f. 4.) At Ankerdine Hill the formation is charged with the casts of the *Atrypa hemisphærica* (Dalm.), Pl. 20. f. 7., *Terebratula decemplicata* (Nob.), Pl. 21. f. 17., and other fossils.

In the thick-bedded grit on the eastern slopes of this hill, are impressions of what are supposed to be fucoids; but they are extremely imperfect and cannot be strictly identified by any botanist who has seen them. This grit is made up of an intimate mixture of fine grains of white quartz and pink felspar, while the rents and faces of the stone, as well as the cavities which give the form of the above plants, are slightly coated by a film of hydrate of iron. The colour is a dingy purple. This formation is lost from Ankerdine Hill (its most northerly extension) to a point three miles south of the Teme, when it reappears in the dome-shaped hill of Old Storridge, throwing off to the west the younger formations above described. (Pl. 36. f. 6.) It is thence prolonged by Rough Hill to Cowley Park Woods, near which it is interfered with by small protrusions of syenite. After being cut out and deflected from its south-south-easterly strike by the great body of the intrusive rock, only a few of the upper beds are seen, as in a new road on the flank of the chain east of Mathon Lodge, till we reach the northern end of Eastnor Park. (See Section, Pl. 36. f. 7.) Here, the strike being reversed, or to the south-south-west, (in conformity with that of the overlying formations), the Caradoc sandstone is expanded, ranging along the Obelisk Hill, and occupying the whole of Howler's Heath, where it terminates in another dome-shaped mass, similar to Storridge Hill. It is here flanked on the south by the New Red Sandstone.

In this course the Caradoc formation, as in Shropshire, exhibits in descending order, first a bastard limestone charged with encrinites, &c., and next a zone of thin-bedded, flaggy, greenish-grey sandstones, alternating with shale; in some places, as near Merry Hill, very hard and siliceous; in others, as in the Obelisk Hill of Eastnor, soft and fragile. In some of these flags are the same fossils as near Acton Scott and Hope Bowdler in Salop. (See List.) In a lower zone of the formation, (at the Paper-mill west of Old Storridge Hill), we have quartzose calcareo-grits, similar in composition to those of Nash Hill near Presteign, and of Horderley in Salop, and which like them contain the same casts of *Pentamerus oblongus*, and the prevalent corals.

Other beds near the Obelisk at Eastnor are dingy purple sandstones, undistinguishable from many described in this formation in Shropshire. In these beds are not only casts, but even shells themselves; one of them is the *Nucula Eastnori*, (nobis), Pl. 20. f. 1. Some of the coarse grits of this formation in Old Storridge Hill, and also at Howler's Heath, are remarkably hard, thick-bedded, and contain much felspar in small grains: a very felspathic variety occurs on the flank of

Midsummer Hill, where it is pierced by the syenite. On the western flank of Ragged Stone Hill, where the high road from Worcester descends from the Malvern ridge, are quarries of pale-green, fine-grained, slightly micaceous, earthy sandstone, as represented in this wood-cut.



86.

The mass of the rock is apparently void of regular laminæ of deposit, but it passes upwards into hard, flaglike, and highly micaceous layers. Although this sandstone is traversed by numerous vertical and oblique rents, it is on the whole a fine free-stone, capable of being worked into any form, and might be termed green sand with as much propriety as any rock in the geological series. Judging from the structure of this sandstone and its proximity to a great fissure of eruption, I am disposed to think it may have been formed during submarine volcanic eruption, and is, therefore, similar in some measure to certain rocks on the sides of Caer Caradoc and other parts of Shropshire.

On the whole, however, the predominant colours of the sandstones and grits are dingy-red or brownish-purple, as in Shropshire. With the exception of the upper band, calcareous matter does not seem to be so prevalent as on the western side of Herefordshire.

On the west flank of the Malverns, the south-westerly strike of the strata, and the southerly direction of the Malvern chain, necessarily produce an expansion of the lower formation, caused by the divergence of the ridges which are respectively composed of syenite and upper Silurian deposits. (See Map.) At this point, therefore, strata still lower than the grits and sandstones above described, are brought to day in highly inclined and contorted positions, west of Key's End Hill, and at the White-leaved Oak. They consist of very thinly laminated, perishable, bluish, slaty shale, with bands of hard, compact, flaglike sandstones. Though these black shales and flags may represent the Llandeilo formation, I have not detected organic remains to complete the analogy; it would be therefore premature to assert that this member has any distinct existence in the east of Herefordshire[1]. Though it is highly probable that we are here presented with a miniature development of the whole series, and that the black schist and shale represents the lower rotch of Caermarthenshire and Pembrokeshire, which there constitutes the beds of passage into the Cambrian System. (See p. 357.) The full succession of the Silurian series, between the syenite of the Malverns and the Old Red Sandstone, is beautifully exposed in a transverse section from Midsummer Hill to Ledbury. (Pl. 36, f. 8.)

Such is a brief outline of the structure and disposition of the Silurian rocks on the western flanks of the Malverns, and the range thence to the Abberley Hills. Further analogies may be worked out by those interested in these tracts, by a reference to the preceding chapters, in which the full types of the same formations are described. To comprehend the nature and amount of the dislocations and undulations to which these masses have been subjected, the reader, after examining and comparing the various

[1] Some of the associated shale is so black, and decomposes so readily, as to produce a surface very much resembling that of certain coal-fields. Indeed, trials for coal were made in this spot, and hence the name of Coal Hill has now become fixed, (see Ordnance Map,) as if to deter all future speculators from such absurd attempts.

sections (Pl. 36.), must then peruse the following pages upon the syenitic and trap rocks of the principal ridge, and the effects produced by their intrusion upon the stratified deposits. The organic remains are described in subsequent chapters expressly devoted to them.


87.

*The Malverns, as seen from the Vale of the Severn south of Worcester, from a drawing by Mr. H. E. Strickland.*

## *Trap and Altered Rocks of the Malvern and Abberley Hills, followed by an account of the principal Dislocations of the Strata.*

The Malvern Hills, when viewed from the east, as represented in this vignette, or from the north-east as in the sketch p. 78, form one of the most striking features in the interior of the kingdom; their steep arid sides and sharp outline exhibiting a marked contrast to the soft and undulating grounds, composed of New Red Sandstone and marl, which occupy the valley of the Severn. On the opposite side, as seen from Herefordshire, they do not convey the same idea of a narrow mountain chain, their western flank being encumbered with other hills and buttresses, constituting the Silurian and Old Red Sandstone systems. (See vignette, p. 409.)

The Malvern Ridge is essentially of volcanic origin, and its component parts were long ago admirably described by Mr. Leonard Horner[1]. It is, indeed, remarkable, that at a time when the intrusion of rocks of igneous origin through sedimentary deposits was received with distrust, or warmly contested, he should have drawn such clear inferences from dislocations of the strata adjacent to the trap.

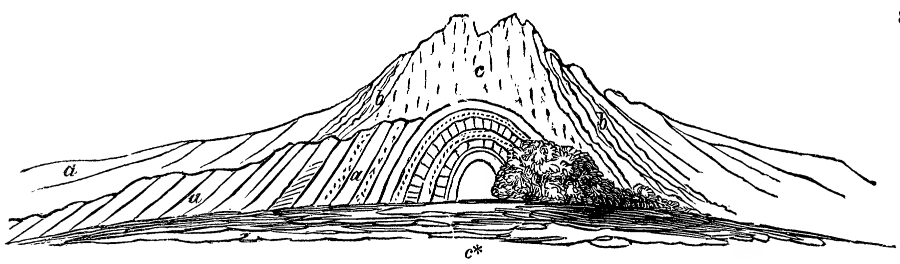
The prevailing rocks are varieties of syenite, consisting of quartz, felspar, and hornblende. A granitic compound of quartz, mica, and felspar, however, occurs: but, as Mr. Horner correctly states, it does not present the appearance of the true granite of Cornwall or Scotland; and it passes into syenite. One of the very finely grained varieties is of a purplish-brown colour, and sometimes contains a small quantity of magnetic pyrites, and slender veins of compact epidote; and in the fissures are crystallized sulphate of barytes, and minute rhomboidal crystals of ferriferous carbonate of lime. Epidote is abundantly disseminated through some portions of this rock, chiefly on the northern

[1] Geological Transactions, Old Series, vol. i. p. 281.

face of the End Hill, usually in a compact or granular state, and in small yellowish green veins ramifying through the granitoid and syenitic rocks. Again, there are transitions into compact felspar, generally much fissured, the surfaces of the cracks being covered with yellow oxide of iron, and occasionally with small crystals of spathose iron and calcareous spar. These felspar rocks are largely cut into on the sides of the high road from Malvern to Ledbury, which crosses the hills between the Worcestershire and Herefordshire Beacons. At Swinyard Hill the rock is granitic, containing very minute scales of mica, but it graduates into syenite and greenstone.

Besides these decidedly unstratified rocks, there are parts of the flanks of the hills in which the same minerals are arranged more or less in layers, and to which Mr. Horner affixed the term of gneiss. Some varieties of the latter may, I think, be considered simply as altered rocks of the Silurian System. Among these, a species of contorted chlorite slate is very frequent. The chlorite, which is scaly and foliated, takes the place of mica, and alternates with quartz, the two minerals being generally in parallel laminæ, but sometimes the quartz is disseminated and mixed with the chlorite. On the whole, the rock has much the aspect of a chlorite schist in Anglesea, described by Professor Henslow. (Cambridge Phil. Trans., vol. i.) There are also, on the western flanks of Midsummer Hill, stratified rocks of ambiguous character, composed of quartzose hard conglomerates, with lumps of compact felspar and much of that mineral disseminated; from their composition it is difficult to suppose they have not been connected with the volcanic origin of these hills. These, as well as the grass-green, felspathic, sandstone of Holly Hill, described p. 416, may be referred to that intermediate class of rocks, and to which the name of volcanic grits has been applied. Under this supposition, we must imagine that in the manner previously explained, submarine volcanic ebullitions were in activity upon this line of fissure during the earliest accumulations of the strata of the Silurian System, and that long after these deposits had been formed, the present syenitic chain of the Malvern burst up, dislocating and altering the adjacent strata. At the White-leaved Oak, between Ragged Stone and Key's End Hills, the trap rocks (*c*) are contracted into a small dyke (*c**). To the north of this hamlet, the flaglike sandstones fold (*a*) concentrically around this dyke, dipping off sharply to the west.

88.




The arch is broken near the summit, but as the chloritic and micaceous schists appear on the contiguous slope of the hill, dipping to the east, there can be little doubt that the peculiar mineral characters of this rock were due to volcanic agency. Indeed, at the extremity of the ridge on Key's End Hill, the chloritic slaty beds are twisted and contorted amid great dykes of compact felspar rocks, and impure syenite. Another proof of the alteration is near the summit of the Worcestershire beacon, where a mass of quartz rock occurs, which doubtless was produced in a manner similar to that on the flanks of the Caradoc, the Wrekin, &c., (see pp. 227, 233.)

Let us next direct our attention to the north end of the range, where Mr. Horner's description terminates. Beyond the End Hill are two bosses of trap, the most southern of which is cut through

at Cowley Park, by the road from Great Malvern to Bromyard. The other is 200 or 300 paces to the north, on the opposite bank of a little stream called Whippet's Brook. *These knolls represent in miniature, the whole chain of the hills.* The centre of the first boss consists of greenstone, having upon each side reddish felspar rock, both granular and compact. On the western flank, dark purple, red and green marls are thrown up in vertical beds, with much decomposed matter between them and the dyke, and the water saturated with the ferruginous colour of this clay, has, in overflowing, discoloured the adjoining trap. On the eastern side is a quartzose sandstone, almost in the state of quartz rock, the strata being vertical; and a little beyond this, it is succeeded by conglomerate quartzose grit. The little knoll which affords this section, rises only about thirty feet above the road. The dislocated and altered strata on its sides, are evidently the grits and sandstone of the Caradoc formation which we trace to large masses in Old Storridge Hill on the north, and Howler's Heath on the south. In the other knoll, north of Whippet's Brook, the flanks of the syenitic greenstone are wrapped round by highly inclined beds of quartzose felspathic conglomerate, which has been largely quarried for a roadstone. This, therefore, is perfectly analogous to the cases of hard and vertical conglomerate, and volcanic grits, which are thrown off the western flank of the syenite of Midsummer Hill, and other points of the Malvern Hills. The direction of these knolls points to the trappean hills which reappear on the left bank of the river Teme between Knightwick Bridge and Abberley; and along the intermediate space, ridges of the Silurian rocks are thrown up in dislocated masses, the general strike of which is parallel to the main direction of the intrusive rocks; namely, from S. and by W., to N. and by E.

### *Range of Trap between Knightford Bridge and Abberley.*

The trap rocks which occasionally protrude along this line, in a direction from south to north, have not yet been described, nor has their position been marked upon geological maps. They rise into several hills, and constitute the nucleus of that ridge, which is the distinct prolongation to the north of the Malvern Hills, and rising through the Silurian rocks before described, further separates the Old Red Sandstone on the west, from the New Red Sandstone on the east. The chief masses of trap along this line, constitute the round hills of Berrow, Woodbury, and Abberley, but exhibit nothing more of their structure than can be detected in small protuberances peering through the verdant pastures with which they are covered. They all consist essentially of "concretionary trap[1]," having a base of greenish-grey, dingy-green, and purple compact felspar, sometimes containing minute crystals of common felspar[2]; when very finely concretionary, as above the Hundred House, the rock is with difficulty distinguished from a grit, and where the felspar has decomposed, presents a mottled surface. In Woodbury Hill, the structure is more largely concretionary than in Abberley Hill. Between this hill and Abberley, is a singular conical hillock, called Round Robin, of the same rock, but of a very red colour, and approaching more to a syenite. In Berrow Hill the structure is coarsely concretionary, felspar of deep red colour being predominant.

I fortunately discovered one little boss of syenite, which has recently been cut into in the de-

[1] The Clent Hills on the opposite or eastern bank of the Severn, are precisely similar in composition and in their forms of disintegration. They will be described in the chapter on the Dudley coal-field.

[2] It is here termed *Jewstone,* a prevalent name in Salop and Worcester for any hard trap rock. It is used for the roads, and is strongly contrasted with the soft decomposing *Mudstone* of the Silurian System.

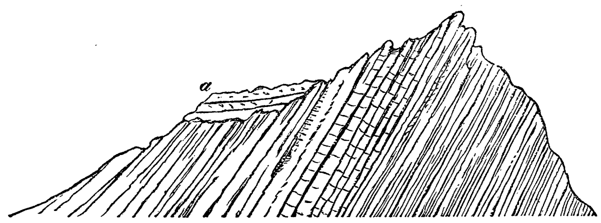
pression north of Berrow Hill, three quarters of a mile west-south-west of the village of Martley, and near the junction of the Old and New Red Sandstones. This rock is made up of flesh-coloured, compact felspar, white quartz, and silvery mica, and passes into a mass undistinguishable from several varieties of the syenitic greenstone of the Malvern Hills. The discovery of this boss of true Malvern rock on the strike of the main direction of the chain, and *in the midst* of the concretionary trap of the Abberley Hills, is a satisfactory and additional proof of their common origin, particularly when coupled with the existence of a syenitic dyke at Brockhill, proceeding from the western flank of these hills, and cutting through the Old Red Sandstone. (see p. 186.) Like the cases north of Malvern and at Brockhill, this little hillock of syenite appears to have been intruded into the Old Red Sandstone, but its relations are ill exhibited, not having been much worked into upon its flanks. Owing to the sloping and unbroken sides of the trappean hills south of Abberley, clear examples of these contacts between the stratified and unstratified rocks, so frequently pointed out in other parts, are not met with; but in the debris on the sides of the hills, specimens are repeatedly found of veined and hardened sandstone, identical with the altered strata on the sides of the Brockhill dyke of syenite.

### *Dislocations.*

The effects produced by the elevation of the Malvern and Abberley Hills are perhaps more striking than in any other part of England. Of all these dislocations, the most remarkable extend from near Abberley Lodge on the north, to Hill End on the south, a distance of about five miles, throughout which the Old Red Sandstone, Ludlow, and Wenlock rocks are completely inverted, the *younger* formations being overlaid by the *older*. Any transverse section made from west to east across the Abberley Hills, displays this phenomenon. In the principal hill, or Abberley Hill, properly so called, the Ludlow formation, having a central zone of impure limestone, is thrown up into the escarpment, and near the northern extremity of the ridge has a strike 8° east of north and west of south, and a dip to the east at angles varying from 35° to 80°, whilst the Wenlock limestone is found at one point only, and at a much lower level, arched over and violently contorted. The same confusion prevails in the culminating parts of the ridge, between the Hundred House and Abberley, but here the Wenlock limestone is entirely cut out for a certain distance, and replaced by trap rocks. Not only is the Ludlow formation exposed in violently contorted strata in the quarries above Abberley, but there are even patches of Old Red Sandstone upon the higher parts of the hill, as seen on the sides of the high road from Ludlow to Worcester, (see Pl. 36, f. 1.) Where the Wenlock limestone is found again, to the south of this scene of convulsion, it is in nearly vertical strata, occupying a lower zone; and the beds slightly thrown over from the perpendicular, are singularly bent and broken, appearing as if they folded round a nucleus of eruptive rock.

In Walsgrove Hill, a deep quarry cut into the side of the hill for the extraction of the impure limestone of the Ludlow rocks, first taught me that the Silurian formations had been really overturned. (Pl. 36, f. 2 & 3, and this wood-cut.)

89.



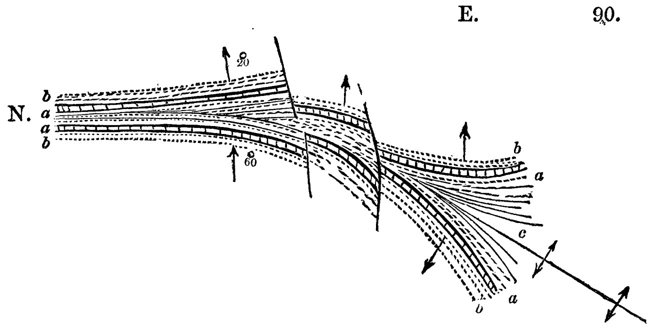

*a.* Coal-grits, &c. *h.* Lower Ludlow. *g.* Aymestry Limestone. *f.* Upper Ludlow.

When examined in detail, the *underlying* beds (*f*) are seen to consist of the Upper, and the *overlying* (*h*) of the Lower *Ludlow rock*, the inclination exceeding the vertical by about 20°. Grits of the coal-measures (*a*) adhere in broken patches to the side of the elevated mass, and small troughs of coal have been worked out in the depressions on the eastern side of the ridge, thus teaching us, that one, if not the chief dislocation, was posterior to the coal measures.

From this point, the Ludlow formation is clearly exhibited in the reversed order of superposition for about four miles; the angle of reversed dip increasing as the ridge advances to the south. On the sides of the hills there are various natural sections of the Ludlow rocks dipping at angles of 30° to 40° to the east, whilst the Old Red Sandstone occupies the valley *below* this escarpment of inverted strata. (See Section, Pl. 36. f. 4.) The proofs of these inversions are completed by prolonging a transverse section to the east, and the parallel ridge of Wenlock limestone is found to be also tilted over; the beds, with partial exceptions of curvature, conformably *overlying* those of the younger formation, and at angles varying from 45° to 60°. So symmetrical indeed is the reversal in this part of the range, that any geologist who had not previously made himself acquainted with the true order of superposition, would naturally conceive the Wenlock limestone to be younger than the Ludlow rock, and the Ludlow rocks than the Old Red Sandstone.

The convulsed state of the Wenlock limestone, near the southern termination of the Abberley Hills, one mile north of the village of Martley, is explained in this ground plan.

90.



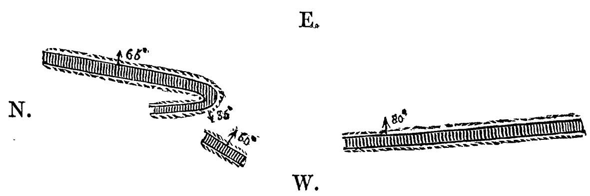

*a.* Thick-bedded limestone.
*b.* Thin nodular or "bumble" beds.
*c.* Axis or split produced by the syenitic eruption[1].

[1] This ground-plan is simply an enlargement of what is represented in the Map.

Advancing from Ridge Hill and Callow Farm to this place, in two ridges trending from N.N.W. to S.S.E., one of which dips 60° the other 20° to the east, the limestone of the principal branch is suddenly wrenched round and split into a diverging fork, and occupies a broken saddle; the separated masses of which dip in opposite directions as in the above wood-cut. It is instructive to observe that the mean direction, if prolonged from the centre of these yawning masses, terminates precisely in a little boss of syenite at the foot of Berrow Hill, and hence there can be little doubt that the direction of the fissure was determined by the eruption of that rock, in a line proceeding from thence by Kingwood Common, and the Noak, to Hill Side. In Tinker's Copse, Collin's Hill, and Ankerdine Hill, the strata of the Caradoc sandstone form an irregular anticlinal, marking the prolongation of this disturbance, whereby the impure limestone and shelly sandstones of Collins Green and Hay Copse are thrown over to the E.S.E., whilst the Caradoc sandstone of Ankerdine Hill dips S.S.W. A glance at the map will show that the Teme escapes through a great fissure, and at a point of extraordinary convulsion; for on the left bank, the Caradoc sandstone is heaved up into a lofty hill, throwing off the Old Red Sandstone to the west; whilst on the right bank the rocks of the Silurian System, being denuded and invisible for a short distance, are covered by a thick mass of conglomerate of the New Red Sandstone of Rosemary Hill. (See p. 53, and Pl. 29. f. 4.)

When again met with, in the prolongation of this ridge to the south of the river Teme, the Silurian rocks have resumed their natural positions; the Ludlow formation regularly overlying the Wenlock limestone, and passing beneath the Old Red Sandstone; and finally the regular order is still more clearly defined by the Caradoc sandstone rising from beneath the other groups in Old Storridge Hill. (Pl. 36. f. 5.) The convulsions, however, to which the strata have been subjected are again very apparent, a remarkable example occurring at Crew's Hill, between Alfrick and Suckley, thus:

91.

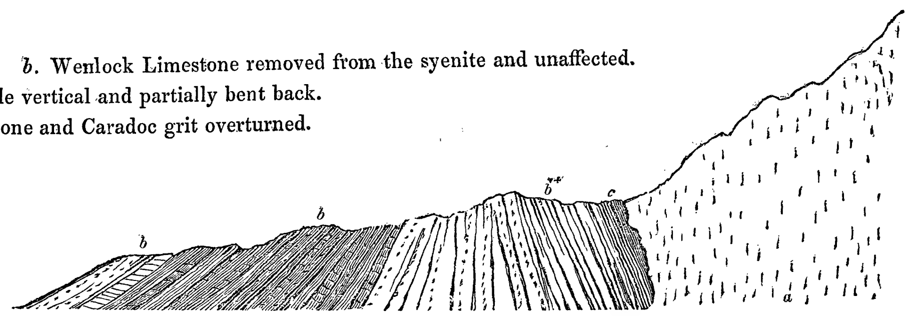



The arrows indicate the points to which the strata dip.

The direction of the strata in this portion of their course is changed from north and south, to a few degrees east of south and west of north. By this strike, each formation successively impinges upon the main chain of the Malvern Hills, which trends from north to south, and the result is such as might naturally be expected. As they approach the syenite, the Caradoc sandstone is first thrown into vertical positions, then traversed by small bosses and dykes of the syenite, as explained p. 419., and finally cut out by the great mass of that rock. Next the impure limestone and grit, or upper beds of the formation, striking upon the western flank of the syenitic hills, are not only ren-

dered vertical, but are partially bent back, as in this wood-cut, thus presenting the same phenomena as in the Abberley Hills, though the degree of inversion is less.

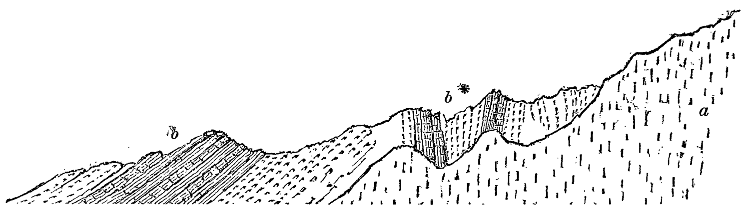
92.




*a.* Syenite. *b.* Wenlock Limestone removed from the syenite and unaffected.
*b**. Wenlock shale vertical and partially bent back.
*c.* Impure limestone and Caradoc grit overturned.

In the description of the Malvern Hills, Mr. Leonard Horner, with his usual sagacity, remarks upon the singular appearance which these strata present, of dipping towards the syenite, where he adds, " they seem to have been raised not only into a vertical position, but even thrown back, and in some degree inverted[1]." The order of superposition of the ancient stratified deposits, was at that period necessarily so incomplete, that no one could have proved the beds had been overturned; and thus we see the value of establishing the succession of the Silurian System. The section represented in the above wood-cut, which is in fact only a part of the coloured section (Pl. 36, f. 7.), was recently laid open by cutting a new road to Mathon Lodge. So long as the Wenlock formation occupies the immediate coast (if we may so speak) of the syenite of the Malvern Hills, so far the strata are violently broken and disturbed, particularly on the steep acclivities of the Hereford Beacon, as in this wood-cut.

93.




*a.* Syenite. *b.* Wenlock Limestone unaltered. *b**. Wenlock Limestone broken and altered.

At this remarkable point is a great change in the direction of the strata. They strike to the S.S.E. until they reach the Malvern syenite; and then they are thrown into vertical and disjointed masses, having a north and south strike, accommodated to the western flank of the intrusive rock, and finally jut out to the south-west in low parallel ridges. As the chain of syenite continues its course to the south, whilst the Wenlock and Ludlow formations diverge to the south-west, the interval between these lines affords space for the elevation of the Caradoc sandstone, which resumes its regular place, dipping conformably under the younger rocks, its lower members only being affected by the syenite on which they rest. The transverse section (Pl. 36.

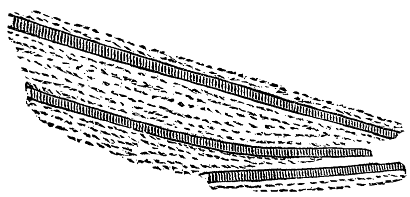
[1] Geological Transactions, Old Series, vol. i. p. 320.

f. 8.) across these ridges, explains the full and conformable development of all the formations on this point, and also the flexure and break of a portion of them on the outer and parallel zone extending to Ledbury. There, the southerly strike being resumed, it is beautiful to observe how at the point of meeting of these conflicting directions, the formations are heaved into domes; a phenomenon similar to that which we shall afterwards notice in the Dudley district. The mean direction, therefore, of the Silurian Rocks from the northern point of the Abberley Hills to the southern termination beyond Ledbury, a distance of twenty-three miles, is from north and south, the *south-south-easterly strike* of the strata from the Teme to the Malverns compensating for the south-south-westerly near Ledbury.

Amid the various faults and breaks along this line are some of very singular character; but most of the apparent lateral shifts which the colours on the map would indicate, can be accounted for by the discrepancy of the angles of inclination of the strata, which have been disjointed by these cross fractures.

To the north-west of the Malverns, near Batchelor's Bridge, where the Wenlock limestone is fully developed and conformably arranged, it has, as before stated, three workable bands of limestone, separated by concretions and shale. Where the formation approaches the Malvern Ridge, it is interesting to watch the effects produced upon those subordinate members. The three bands near Brand Lodge converge and almost unite in one mass; the shale and concretions appearing to have been squeezed out.

Ground-plan of three bands of Limestone near Brand Lodge.



94.

This might be attributed to the natural thinning out of portions of the included beds, but we no sooner turn round the adjacent trappean promontory of the Herefordshire Beacon, than we again meet with the three bands of limestone in vertical, distorted, or highly inclined beds at different levels on its steep slopes, each calcareous mass separated by a *considerable* breadth of shale. The same is observed in the ridgeway of Eastnor Park.

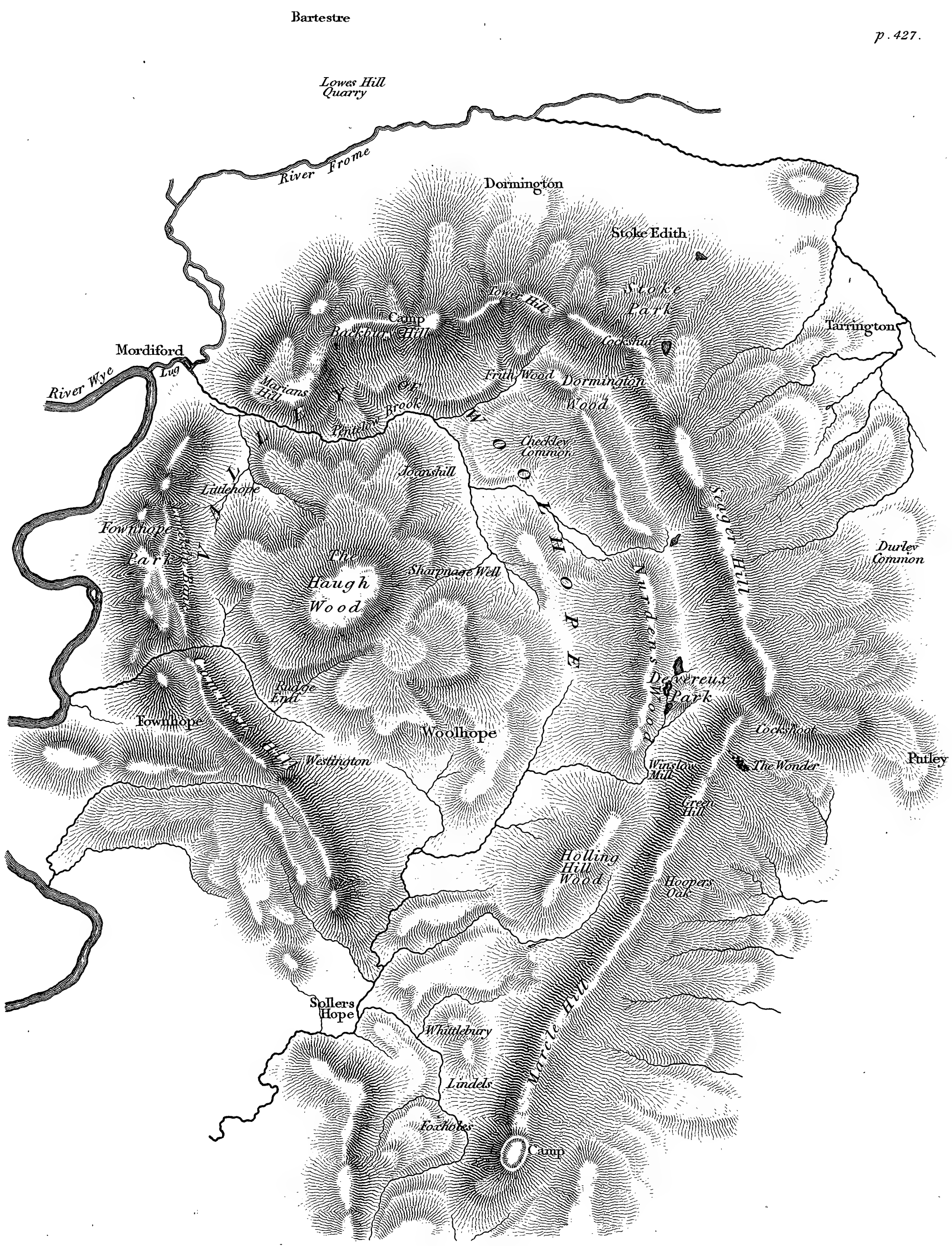
The phenomenon, however, most worthy of attention, is the reversal of the strata. In the Abberley Hills, where the effect is of the greatest intensity, the eruptive rocks rising through the tilted deposits are at hand, to afford an explanation of the agency employed in effecting so great a revolution. With the exceptions of the Brockhill dyke (p. 186), and the rock near Martley, the trappean rocks of Abberley are not, however, cut into by any natural or artificial excavations to show the points of contact, though we can have no doubt that their eruption dismembered the strata, because the various Silurian deposits occur in disjointed masses, at *different* heights on the sides of

those hills, the summits of which, as in the Abberley and Woodbury Hills, consist exclusively of rocks referrible to an igneous origin. If, however, there could be any doubt respecting the agency which produced these remarkable effects, it is instantly dispelled by an examination of the western slopes of the Malverns, where the inverted or overturned strata are admirably laid open as above represented, close to the overshadowing and bulging mass of the syenitic chain. The submarine volcanic action which raised the Malvern ridge, may easily be supposed to have forced up the contiguous strata; first to high degrees of inclination, next to verticality, and finally to have bent them backwards upon their axis, into their present positions. (Pl. 36, f. 7.) The eruption of the trappean rocks of Abberley and Woodbury has, therefore, doubtless produced a more intense movement of reversal of the strata in those hills. Unlike the beds on the western flanks of the Malverns, which, in proportion as they recede from the edge of the eruptive chain, regain their regularity and gradually *resume* their regular positions, the older formations dipping away beneath the younger; the same deposits in the Abberley Hills present the ends of their highly inverted strata to a valley composed of the Old Red Sandstone, the younger rock being surmounted by the older strata of the Silurian System! (Pl. 36, figs. 1, 2 & 3.)

Such phenomena are of high interest, as pointing out in our own country what has been indicated by geologists who have laboured in Alpine regions, where inversions of the strata are frequent. Professor Sedgwick and myself, as already stated, traced phenomena of this character throughout a long range on the northern flanks of the Austrian Alps, where the younger strata of the green sand appear to plunge under the older Alpine limestone, and these again under the more ancient rocks towards the centre of the chain. (See Geol. Trans., N. S., Vol. iii. p. 203.) This inverted order in the Abberley Hills could never have been established without previous determination of the regular and uniform succession of similar deposits over a large region where they are *un*disturbed; while all the accompanying phenomena are so clearly explained upon the western flanks of the Malvern Hills, that there is no longer any possibility of avoiding the inference, that the volcanic agency, which threw up this line of trap rocks, was directly the cause by which the strata were forced up and folded back.

That one great eruption of the Malvern rocks took place after the accumulation of the coal-measures, is proved by various dislocated carboniferous patches at the Abberley Hills. Further, from the highly inclined position of the beds of New Red Sandstone near Great Malvern, it is almost certain that this chain was also partially raised "en masse," after the deposition of that formation. (Pl. 36. f. 7.) Whether the movement which affected the Red Sandstone was the same as that which broke up the coal-measures is not easily determined, though we have no difficulty in affirming, that upon this *same line of fissure*, volcanic action had been in play during the accumulation of the Silurian System, and that the strata then in existence were thrown up by outbursts anterior to the formation of the coal beds, which rest unconformably upon the edges of these older rocks.

There are, therefore, indications of several periods of movement, one of the last of which was probably that, which trending from N. to S., and from N. and by W., to S. and by E., was caused by a great eruption of the Malverns, accompanied by other lateral and parallel movements. The N.E. and S.W. strike, so dominant between Ledbury and the principal mass of syenite, was the original direction of the deposits, while their fractured condition was probably the result of the north and south, or last movement to which they were exposed. Similar effects of dislocation, proceeding from the intersection of conflicting lines of strike and on a much larger scale, have been pointed out in Pembrokeshire.




for Geological Colors, see the General Map.

J. Gardner, sc.

# CHAPTER XXXII.

## VALLEY OF ELEVATION OF WOOLHOPE.

*Introduction.—Form of the Valley.—Description of the Silurian Rocks which constitute its encircling ridges.—Ancient dislocations which determined its form, fractures, and drainage.—Modern dislocations and landslips.—Drifted matter.* (See General Map, enlarged Map opposite page, coloured sections, Pl. 36. figs. 9*a* and 9*b*. and wood-cut p. 428.)

THE phenomena of valleys of elevation in rocks of sedimentary origin were first brought into prominent notice in England by Dr. Buckland, in an able sketch of the district of High Clere and Kings Clere[1]. Since that period the attention of geologists has been directed to certain crateriform cavities, which, composed of trap or volcanic rocks, have been termed by Von Buch "craters of elevation," and their external folds having an eccentric dip are supposed to have been forcibly raised from the centre into their present positions. This opinion, ably supported by some leading geologists, including MM. Elie de Beaumont and Dufrénoy, has met with equally powerful opponents in Mr. Lyell, M. Constant Prevost and others. The followers of Von Buch contend, that the relative position of these masses and their transverse rents, demonstrate upon mechanical principles, that violent and sudden expansion from centres of eruption could alone have produced such results,—their opponents asserting, that in lithological structure and method of arrangement, the strata composing many of these so called " elevation craters" are nothing more than the natural products, whether submarine or subaerial, which being vomited from craters, have fallen upon or flowed down their sides. It is not my intention to enter into this warmly agitated question; but, notwithstanding the eminence of the rival disputants, I cannot avoid expressing an opinion, that in this, as in many other points of geological theory, discrepancies of opinion may often be reconciled, if the contending parties would examine for themselves the same natural phenomena. Mr. De la Beche, in his able work, " Researches in Theoretical Geology," p. 112, has well observed, that " amphitheatres or valleys of elevation merely require the ejection of volcanic matter through their centres to become the much disputed craters of elevation." Nature, therefore, it appears to me, may be so appealed to by contending

[1] Geological Transactions, vol. ii. p. 119.

theorists, that their opposite views may equally be sustained by physical evidences; for on the one hand cases may be cited, where stratiform masses, once horizontal, have been heaved up into dome-shaped forms, dipping away from a common nucleus, like the valley I am about to describe; while on the other, there must, according to modern analogies be instances, where accumulations of indisputable volcanic origin have been actually placed in their present relative positions, by ejections from the mouths of craters, both under the sea and under the atmosphere.

Whether the stratified masses so arranged, be purely sedimentary, or of mixed aqueous and igneous origin, does not much affect the question. It is not fair to contend that every rock, the structure of which bespeaks a volcanic origin, and which has a quâ-quâ versal dip, was *originally* arranged in that position. The surface of the globe abounds in large stratiform and horizontal "couleés" of volcanic rock, which if upheaved by internal forces, *might* appear domes of elevation like this of Woolhope; and in the preceding pages I have already cited many examples of stratified masses of igneous origin, (volcanic grit) &c., some of which form amphitheatres of elevation. Now if such masses were purely of volcanic origin, it might be contended that they owed their quâ-quâ versal dip to crateriform action: but as they are interlaminated with sedimentary matter containing organic remains, there is no doubt that they have been accumulated under the sea, in undulating or slightly inclined strata, and have since been thrown into their present positions.

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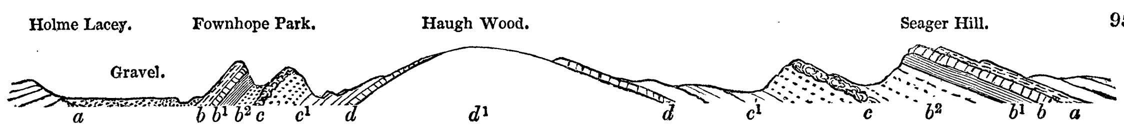
After this preamble, I proceed to direct attention to a most remarkable and symmetrical example of these phenomena which occurs within the Silurian region[1]. Though not known in Herefordshire by any distinguishing name, I have called it the valley of Woolhope, because that village stands near its centre. The surrounding villages are Dormington, Stoke Edith, Putley, Much Marcle, Sollers Hope and Fownhope, all of them situated upon the Old Red Sandstone (*a* of this wood-cut) near its junction with the Ludlow Rock *b*.

WOOLHOPE VALLEY.

95.




| | | | |
|---|---|---|---|
| A. OLD RED SANDSTONE. | B. LUDLOW FORMATION. | C. WENLOCK FORMATION. | D. CARADOC FORMATION. |
| | *b*. Upper Ludlow. | *c*. Wenlock Limestone. | *d*. Caradoc or Woolhope Limestone. |
| Lower part only seen. | $b^1$. Aymestry Limestone. | $c^1$. Wenlock Shale. | $d^1$. Caradoc Sandstone. |
| | $b^2$. Lower Ludlow. | | |

[1] For other examples of similar phenomena, see accounts of the valley of elevation of Wigmore Lake (the Ludlow promontory), p. 238; and of Usk, p. 438.

This elevated mass is of an ovoidal or pear-shape, the major axis from north-west to south-east being six miles from the village of Dormington at the larger end, to the farm of Lindels near the south-eastern apex. The transverse diameter measures four miles, from the village of Fownhope on the south-west, to the outward flank of Seager Hill on the north-east. Within this area the three upper formations of the Silurian System are elevated into concentrical and conformable masses, the strata of each dipping outwards from a common centre, and the whole passing beneath the Old Red Sandstone.

I shall in few words describe each of these elliptical-shaped masses, proceeding from their centre to their flanks, and beginning therefore with the most ancient of the three deposits.

The central mass called Haugh Wood is about two miles long, by one and a half broad. The strata exposed in the central portion of this nucleus are quartzose grits of the Caradoc sandstone ($d^1$ of wood-cut). These beds rising to a height of upwards of 600 feet in the centre of the wood, where they are nearly horizontal, dip away on all sides at angles not exceeding 12° or 15°. From the gentle and equable curvature of the surface of this central dome, the strata are little fissured and the lower parts of the Caradoc sandstone are not exposed; thin bedded siliceous sandstone and quartzose grit being the lowest beds visible.

As in Shropshire (p. 271), or on the west flank of the Malverns (p. 414), the uppermost member of this formation is a hard impure limestone (*d* of wood-cut), occasionally burnt, but more frequently used as a road stone. Folding around the central dome of Haugh Wood, it is well developed near Woolhope, and may therefore be termed "Woolhope limestone." It is quarried at Woolhope, Limburies, Littlehope, Rudge End, Joans Hill and Westerton. (See coloured section, Pl. 36. fig. $9^a$ and $9^b$.) In mineralogical character it is undistinguishable from that of Stumps Wood on the west side of the Malverns, being a hard, dark blue, thick flaglike limestone; the surfaces frequently chequered with transverse septæ, occupied by pink calcareous spar; a few way-boards of unctuous clay lying between the beds.

The next strata in ascending order are composed of shale of the Wenlock limestone, ($c^1$ of wood-cut) which here, as in most other parts previously described, is deeply denuded. Hence its place is marked by a depression, which varies in width from half to three quarters of a mile. Towards the north-eastern turn of the valley, however, where the encircling deposits are most expanded, this shale rises into low hills on the sides of the road leading from Mordiford to Checkley Common, where the strata dip 15° north-east. (See Map.) It is here interlaminated with many thin courses and concretions of impure limestone and hard marl, in which are shells and corals characteristic of the Wenlock formation, together with portions of the *Asaphus caudatus* and other *trilobites*. The soil along this zone is very variable, being rich enough to pro duce hops and wheat where the calcareous matter prevails, but cold and sterile where it is wanting.

Low, wooded hills surround the shale ($c^1$). These are composed exclusively of the Wenlock limestone (*c* of wood-cut), a solid mass of which generally rises to near the top of the ridge, accompanied with the usual small concretionary nodules. This zone, the chief seat of the limeworks of the district, has a valley on each side, the inner one excavated in the Wenlock, the outer in the Ludlow shale.

To describe the zoological remains of this limestone would be only to repeat accounts given of them in other places, a vast number of the characteristic fossils of the formation being present. (See Pl. 12, 13 and 14 and descriptions.) These organic remains, particularly the corals (Pl. 15 and 16.), are most abundant at Fownhope, Winslow Mill and Lindels. The inclination of the beds of limestone is for the most part higher than that of the inferior strata. At Winslow Mill they dip 40°. At Fownhope they are thrown up to 40° and 50°, and at Lindels, where the opposite ridges unite and terminate in an apex, they incline 30° to 40°.

The exterior ridge is composed of the Ludlow formation, which is thrown off on all sides from the central and inferior rocks, plunging beneath the Old Red Sandstone. These Ludlow rocks preserve their usual tripartite subdivision into a lower shale ($b^2$), a central calcareous stratum or the Aymestry rock ($b^1$) and Upper Ludlow rocks (*b*).

The shale ($b^2$) occupies a valley, separating the harder parts of the formation from the Wenlock limestone, &c. The higher part of this shale rises into the steep escarpments of the outer rim, and passing into an argillaceous sandstone, is undistinguishable from the "mudstone" of Abberley or "pendle" of Shropshire.

The calcareous or central member ($b^1$) is the equivalent of the limestone of Aymestry, and with the exception of that peculiar shell, the *Pentamerus Knightii*, it contains the well known fossils of the stratum, such as *Terebratula Wilsoni, Lingula Lewisii, Turbo corallii*, &c. (See Pl. 6.)

From its greater hardness, this rock has resisted denudation more effectually than any other portion of the formation, and therefore constitutes the culminating points. It is used for road making, and at one or two places was formerly burnt; but the superior quality of the adjoining Wenlock limestone supersedes this application of the stone. It forms the crest of the external ridge of the Woolhope Valley, and in Marcle, Seager, and Backbury Hills, rises above all the deposits of the included valley.

The calcareous beds pass insensibly into the overlying argillaceous sandstone or Upper Ludlow rock (*b* of wood-cut), which to the east and north sides, descends into the plain, at angles varying in the different promontories from 35° to 15°, the dip usually decreasing towards the low and fertile region of the Old Red Sandstone.

The western and south-western face of the ellipse, or the ridge extending from Mordiford to Fownhope, is an exception to this gradually decreasing inclination from the lower to the upper strata of the Ludlow rock, that portion of the margin being thrown up at the high angle of 60° to 65°. The actual junction of the Ludlow rock along this frontier with the Old Red Sandstone, is for the most part obscured by detritus, which

near Mordiford is a breccia, and in the plain of the Wye is a thick argillaceous alluvium.

There are, however, instructive sections to the south of Fownhope, where the Ludlow formation occupying the sharp ridge of Paget's Wood and Leigh Wood, plunges at an angle of about 45° to 50° under the Old Red Sandstone, which is there not much denuded, but occupies the hill of Capler's Camp. (See Pl. 36. f. $9^{a}$.)

Excellent detailed sections of the Upper Ludlow rock are visible at many points around the external face of the elevated mass, by ascending from the plain of the Old Red Sandstone to the highest ridge; namely, behind the village and in the park of Stoke Edith; at Dormington and in the slope between Upper Dormington and Backbury Hill; or in Seager Hill, Marcle Hill, Ridge Hill, &c. The best sections, perhaps, are in the deep-sided lane leading from Darley Common to the crest of Seager Hill by Pilliard's Barn, where the strata are absolutely loaded with shells, not merely casts, as is common in this rock, but with the shelly matter as well preserved as in the testacea even of the tertiary period. Several of the most characteristic shells of the Ludlow rock figured in this work have been found in these localities. (See Pl. 5.)

### *Ancient Dislocations of the Valley.*

The arrangement of the rocks above described must be critically examined, before we can account for the physical features of the valley of Woolhope. Some of these features are the results of mineral structure. Thus, for example, we see that the soft shale has been hollowed into depressions, leaving the harder limestone and sandstone as walls or lines of circumvallation. In explaining, however, those transverse gorges in which the waters flow, we must look to the movements which, in elevating this valley, determined its present form and drainage.

The major axis or anticlinal line of the valley ranges from Backbury Camp and Dormington on the N.N.W., to Lindels and Oldbury Hill on the S.S.E. As the strata on the eastern side of this line, dip at a lower angle than those upon the west, the former side is necessarily broader than the latter. (Pl. 36. figs $9^{a}$ and $9^{b}$, and woodcut, p. 428.) Throughout two thirds of the circumference, or that portion of it where the strata are not much inclined, the outer ridge, consisting of the Ludlow rocks, is unbroken by any deep transverse fissures. Slight depressions called "cockshoots," alone separate the higher points of the ridge from each other. Hence the water descends from all this part of the escarpment into the centre of the valley. These "cockshoots" mark the *rudiments* of transverse valleys, and have been occasioned by minor faults or dislocations which have proceeded neither deep enough nor far enough to produce com plete gorges[1]. Had this symmetrical and elevated margin been without deeper breaks,

[1] See other accounts of these *rudimentary* transverse gorges, p. 349.

the lower parts of the valley would be now covered with water, which could only escape when sufficiently high to issue through one of these cockshoots, and the central dome of Haugh Wood would, under such circumstances, be an island in the centre of a lake. Such a condition of things, if it ever existed, was, however, long ago completely changed by the opening of three, deep, transverse gorges, through the south-western segment of the encircling ridges. The largest gorge or that of Mordiford, is traversed by the Pentelow brook, the chief line of drainage of the valley, and the two smaller gorges, by the rivulets of Fownhope and Sollershope, all feeders of the Wye.

It is hardly possible, indeed, that masses composed of hard and stony matter could be brought into their present ovoidal forms, and arranged with a quâ-quâ versal dip, without being subjected to great transverse breaks; for if, as we have seen, even the straight ridges of other tracts, have been affected by dislocations more or less at right angles to their line of bearing, how much more is it to be supposed, that masses of similar rock cannot have been elevated in circular or elliptical forms, without great fractures of the strata! Thus, as might be expected, transverse breaks and faults are observable in the surrounding rocks at many points, the existing ovoidal mass being made up of a number of *separate* pieces, the ends of which were once united. (See map with this chapter.) The greatest convulsions have taken place near the north-eastern turn of the valley, in the Dormington Woods. The Wenlock limestone there ranges in a regular escarpment, the beds dipping north and N.N.E. for the most part, at a slight inclination; but in one place they are thrown down at an angle of 35°; whilst at the end of the wood the strike is reversed to W.S.W., and the beds are pitched abruptly to the south-east. From that point to the north of Fownhope, a distance of nearly two miles, we lose all traces of the Wenlock limestone. This is the only portion of the ellipse, where a large mass of any member of the series is wanting, and the effect is naturally referrible to very powerful dislocation, followed, as will be hereafter pointed out, by denuding currents of water.

The chasm of Mordiford is, indeed, a considerable fault, as shown, not only by the great disruption and loss of the Wenlock limestone, but also by the discrepancy of inclination and direction of the Ludlow rocks, on the opposite sides of the gorge. Between Stoke Edith and Mordiford, these rocks are thrown into broken hilly masses, describing upon the whole a curve, the effect of various breaks and upcasts, many of which may be observed in the beautiful wooded grounds between Stoke Edith Park and the escarpment of Backbury Hill; or on the outer slope of these rocks near Dormington, Priors Court, &c. At Mordiford the Ludlow rock dips 40° north-west, but on the south side of the defile of the Pentelow brook, the same strata project into the narrow ridge of Westwood and Fownhope Park wood, several hundred yards to the west of the line of bearing of the Mordiford rocks, and in a new direction. These beds dip 60° and 65° to the W.S.W.; and, finally, incline to the south-west as they pass from Fownhope to Lindels, where they are last seen.

The Wenlock limestone, the traces of which are lost for so great a distance near Mordiford gorge, reappears in a narrow ridge near Fownhope, where through the high inclination of the strata, it is brought much nearer to the overlying Ludlow rock than on the opposite side of the valley. Hence this western side of the elevated mass is of less width than the eastern, (see Map and Sections.)

At Fownhope, this limestone and the Ludlow rocks have been fissured by the transverse break, through which the little brook escapes to the Wye. This is the second drainer of the Woolhope valley, and though not exhibiting the same amount of denudation as the larger gorge of Mordiford, it presents some remarkable dislocations. Thus, on the right bank of the brook, the Wenlock limestone occupies an oblique position, *un*conformable to the external zone of Ludlow rock, dipping at an angle of 25° to 30°; while on the opposite bank, the same limestone is thrown up to an angle of 70°, the broken ends of a once continuous mass being separated by about 150 paces. (See Map.) This appearance of a lateral shift is thus accounted for, by the higher angle of inclination in the advanced mass. From this point to the extremity of the sharp limestone ridge called the Common Hill, several fractures may be seen, by one of which the rock has been snapped off and placed at *right angles* to its ordinary bearing. The third brook is that of Sollershope, which also flows through a crack in the surrounding strata, but does not present phenomena of equal interest to those of the gorges at Mordiford and Fownhope.

We thus ascertain, that the encircling formations of the valley of Woolhope, have been thrown into an elliptical position, by forces that have broken a chain into many separate masses, which, though still sufficiently connected to form what may be termed ridges, are so far disjointed as we might suppose solid strata to be, which, having once been continuous, and in positions more or less horizontal, had been violently extruded by a force acting from beneath and propelling them outwards from a common centre. The greatest intensity of this force has evidently expended itself in the north-western and south-western sides of the ellipse, elevating the strata to considerable heights, and heaving them into sharply inclined and broken ledges. These results cannot be contrasted with the form of the opposite segment of the ellipse (where the beds being slightly inclined are unbroken) without admitting, that the amount of transverse rupture has in each instance been commensurate with the degree to which the strata were elevated. As the intensity of elevation diminishes to the south-east, the older or central formations successively diminish in height, and the younger deposits approach and fold over each other; so that while the opposite ridges of limestone unite in a low hillock at Lindels, the overlying Ludlow rocks are confluent in the hill of Oldbury. Extending from this point to the S.S.E., and flanked on each side by Old Red Sandstone, this ridge of Ludlow rocks appears like a stalk attached to the pear-shaped mass of Woolhope. (See Map.)

In the next chapter we shall trace the prolongation of this axis of elevation along the narrow ridge or stalk alluded to, as it proceeds to May Hill, and is thence extended to Tortworth in Gloucestershire.

*Modern Dislocations.—Landslips.—The Wonder.*

Passing from the great dislocations of former periods, let us now consider the minor ones of modern date which come under the name of landslips.

The Upper Ludlow rock is strikingly laid bare at several points on the left bank of the Wye, particularly above the high road from Hereford to Ross, in the woody hills of Fownhope Park, and at the brewery, where the high angle of inclination, 65° to 70°, occasions at this day considerable slips of the beds into the low ground beneath.

The most striking example, however, of the sliding down of one mass of strata upon another, occurred on the eastern side of the valley of Woolhope, near the village of Putley, and on the exterior slope of Marcle Hill. Our ancient chronicler Stowe has given a most portentous account of the phenomenon, which is thus described by Camden, vol. ii. p. 443. "Near to the confluence of the Lugg and Wye to the east, a hill called Marclay Hill, in the year 1575, rose as it were from sleep, and for three days moved on its vast body, with an horrible noise, driving every thing before to an higher ground, to the great astonishment of the beholders, by that sort of earthquake I suppose, which naturalists call *Brasmatia* [1]." On visiting the spot I found the phenomena to be similar

[1] Fuller says, "the field moved was twenty acres, and that it travelled fourteen hours, and ascended eleven fathoms up hill, leaving a chasm 400 feet wide and 520 long." Baker, in his Chronicle, gives a much more marvellous account. "In the 13th Queen Elizabeth a prodigious earthquake happened in the east parts of Herefordshire, at a little town called Kinaston. On the 17th of February, at six in the evening, the earth began to open, and a hill with a rock under it, making at first a great bellowing noise, which was heard a great way off, *lifted itself up* and began to travel, bearing along with it the trees that grew upon it, the sheepfolds and flocks of sheep abiding there at the same time. In the place from whence it was first moved, it left a gaping distance, forty feet broad and fourscore ells long, the which field was about twenty acres. Passing along, it overthrew a chapel standing in the way, removed a yew tree standing in the church-yard from the west to the east. With the like force it thrust before it highways, sheepfolds and trees, made tilled ground pasture, and again turned pasture into tillage. Having *walked* in this sort from saturday evening till monday noon it then stood still."—This spot is still called "the wonder."

Drayton notices it thus,

"But, Marcely, grieu'd that he, (the neerest of the rest,
And of the mountain kind) not bidden was a guest
Vnto this nuptiall feast, so hardly it doth take,
(As, meaning for the same his station to forsake)
*Inrag'd and mad with griefe, himself in two did rive:
The trees and hedges neere, before him up doth drive,
And dropping headlong downe three daies together fall:
Which, bellowing as he went, the rockes did so aphall,
That they him passage made, who coats and chappels crusht,
So violentlie he into his valley rusht."

* "Alluding to a prodigious division of Marcle Hill, in an earthquake of late time (CIↃ.D.LXX.V), which most of all was in these parts of the island."—Drayton's Polyolbion, book vii. p. 105. Ed. London, 1622.

The notes in this best edition of the Polyolbion were by the famous John Selden. My friend the Rev. T. T. Lewis, who called my attention to old Drayton, begs me to refer my readers to the whole passage describing the marriage of the Wye and *more lovely* Lugg.

to many *ecroulemens* of Alpine tracts. Dislocated masses of the Upper Ludlow rock, in all amounting to about 20 acres, still attest the extent of the calamity, by exposing gaping fissures between them. Some of the masses have slid so gradually and equably as to preserve the angle of inclination of 12° or 15° which they had before they broke away from the parent mass, and these have trees and grass growing luxuriantly on their summits. Others have been thrown upon their edges into inclined positions. The broken rocks have advanced, however, but a very short distance upon the ground below them, and the slip is therefore quite insignificant, when compared with the " ecroulemens " of the Alps, nor is it by any means so striking as the slip of the Palmer's Cairn near Ludlow. (See wood-cut, p. 248.)

As the strata are slightly inclined in the adjoining ridge, or in that portion of it from which this mass has been detached, it is more difficult to imagine why the subsidence should specially have taken place at this point; though a consideration of the structure of the Ludlow rock will facilitate the explanation. It has been before remarked, that it is a common feature of this rock to be split into lozenge-shaped masses, by joints which are more or less vertical to the surfaces of the strata. We have only to imagine this mass of Ludlow rock replaced in its former position, with several such cracks at its upper extremity, and that water descending from the ridge above, and percolating for ages through the apertures, gradually washed away some underlying, perishable way-boards. We can then readily suppose, that having been so far loosened, it would, upon some slight exciting cause, slide down into the valley beneath. An unusual flood, the breaking up of a long frost, or other ordinary atmospheric changes would in such a condition of things be quite adequate to produce this " wonder," particularly in this district, where the lower grounds consisting of soft clays near the junction with the Old Red Sandstone, are very likely to have given way, and thus to have aided the descent of this mass of rock.

The explanation previously given of similar phenomena in the neighbourhood of Ludlow, may, indeed, be applied to this and all other slips in rocks having the same structure. Owing to the broken condition of the strata, I could not detect beneath the dislocated mass a layer of unctuous shale or fuller's earth which might have facilitated its descent on the inclined plane in the manner before suggested; but I have little doubt that such "*Walker's Soap*" existed, for it abounds in the Ludlow formation of this neighbourhood, and is largely extracted for economical uses at Shucknell Hill[1]. (See Map.) I have minutely described this, because although noticed by foreign writers[2], it has escaped the observation of native geologists. We now learn, that so far from being an isolated phenomenon, it is one of frequent occurrence in the Upper Silurian rocks, resulting naturally from their structure and position.

In the account given of the old chroniclers, no part seems less intelligible, than the

[1] Shucknell Hill, distant only two miles from the northern edge of the Woolhope elevation, is a distinct Silurian mass surrounded by Old Red Sandstone and composed exclusively of Ludlow rocks, the calcareous or central band of which (representing the Aymestry limestone) is exposed in sharply inclined strata and largely quarried for road making. The major axis of Shucknell Hill is from W.S.W. to E.N.E., and therefore at right angles to that of Woolhope, and is coincident with the remarkable trap dyke of Bartestree described pp. 185 and 186.

[2] Bertrand, Révolutions du Globe, Paris. The account is taken from the old English writers.

description of the rock moving *up hill*. This may, however, be explained, by supposing that the phenomenon was seen by persons who fled from the *lower* grounds, and looked back to the scene of dislocation. The first descent of the disrupted rock might easily escape their notice, whilst its long continued effects *in forcing up* mounds of the soft earth, against which it was pressing, might, when viewed from beneath, produce the appearance of a rising of the whole mass.

### *Denudation of Woolhope Valley.*

To return to ancient phenomena.—The denudation of the valley of Woolhope appears to be the natural result of such an elevation, from a common centre, as we have been considering. Shut out by an encircling ridge from the region of Old Red Sandstone, we should hardly expect to find within its area, any fragments of rock transported from surrounding places, and this is strictly true; for there is not a trace of boulders or gravel derived from the Malverns or adjacent chains. Insulated, however, as this mass of Silurian rock now is, it must at one period have been covered with the Old Red Sandstone which surrounds it, and through which it has been forced up. Now if this extrusion had been brought about by a succession of small upcasts, we should naturally expect, that some detritus of the overlying strata would be found *within* the central area; that some fragments of the Old Red Sandstone and Ludlow rocks would be lodged in the depressions encircling the inner dome. Such, however, is not the case, for the valley is one of *clean* denudation, there not being within it a fragment of such rocks, any more than debris foreign to itself. When, however, we reflect upon the nature of the elevation, we see in it the inevitable result of the same powerful operations which have produced the form of the valley. For whether we embrace the hypothesis of a sudden expansion or of a number of shocks, we are compelled to call into play the action of currents, both violent and long continued, to explain satisfactorily the great extent of erosion; and when we see that excavation has proceeded so far, as to groove the broad channels which surround the central dome, and to carry away large portions of the associated rocks, why should we expect to find even a trace of the wreck of overlying strata, which must have been removed, *before* the work of denudation could commence upon the inferior deposits?

If, however, no detritus be observable *within* the valley, we no sooner issue from it at Mordiford, where the only gorge of magnitude opens into the low country, than we meet with accumulations of conglomerate and gravel. These materials have all been derived from rocks belonging to the valley, including finely comminuted materials of the Old Red Sandstone. Such accumulations are cut through to a considerable depth in the road from Mordiford to Fownhope, and are spread out near the mouth of the gorge. In like manner, similar detritus is lodged upon the *external* slope of the elevated tract, frequently obscuring the junction of the Upper Ludlow rock with the Old Red Sandstone.

We thus perceive, that the interior of the valley of Woolhope has been *entirely* denuded of the enormous mass of loose materials, which must have resulted from the breaking up of strata with which it was once occupied; an effect which appears inexplicable, if sudden and violent elevations be not admitted as causes, which may have produced submarine tides or currents, adequate to sweep away such debris. Nor can we look to the transverse chasms, from which large masses of rock have been torn, without feeling certain, that in no former condition of things, could the streams which now flow, have disembarrassed the gorges of so much detritus.

The observations explaining the position of the remarkable outlier of Pen Cerrig Calch, pp. 163—4; those on the denudation of a Silurian group near Usk, p. 441; and the concluding chapters on drifted and alluvial matter, must also be consulted.

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I regret that the description of so picturesque a tract should not have been illustrated by a sketch, the more so as I have been informed (though too late for my object) that some of the most beautiful scenes around Stoke Edith Park have been delineated by Lady Emily Foley. The finest points of view are those from the tops of Seager Hill and Backbury Camp; the latter in particular commanding the whole valley of Woolhope, with May Hill appearing in the distance.

## CHAPTER XXXIII.

### SILURIAN GROUPS OF USK AND MAY HILL.

1. *Usk Valley of Elevation, consisting, like that of Woolhope, of the Ludlow, Wenlock and Caradoc Formations.* (Pl. 36. figs. 23 and 24.)
2. *Prolongation of the axis of Woolhope, by May Hill to Purton and Tortworth in Gloucestershire.* (Pl. 36. figs. 11, 12, 13, 14, 14 *bis*, 15 and 16.)

BEFORE we trace the remarkable anticlinal line[1], which proceeding from the south-eastern end of the valley of Woolhope, passes by May Hill into districts east of the Severn, let us first dispose of the only Silurian tract to the west of that river, which has not been described.

This tract comprises a group, which rising from beneath the Old Red Sandstone of Monmouthshire, near the town of Usk, constitutes an irregularly shaped elliptical valley of elevation, of about eight miles in length by four in width; the major axis trending from Clytha on the N.N.E., to Llangibby and Llandegfydd on the S.S.W. The group is bisected by the river Usk, which after traversing the Old Red Sandstone, enters these rocks by a fissure at the Chain Bridge, having the Cliff called Craig pandu on the one hand, and the lower grounds of Kemeys and Trostrey on the other. After winding in a denudation, the river again exposes similar rocks in the Hills of Llancayo and the Castle of Usk on the left bank, and in the ridges of Llanbadock upon the right.

### *Ludlow Rocks.*

The Ludlow Rocks are very largely developed upon the left bank of the river, and form the hills of Usk Castle, Llancayo, Trostrey and Clytha. At Usk Castle is a clear section of the Upper Ludlow Rock, showing its passage into the Old Red Sandstone; and the lower perishable strata of the same formation are well exposed on the east side of the high road leading to Abergavenny. The flaglike beds of the Upper Ludlow have the faces of their joints occasionally discoloured with a deep red tint, which I have never observed in any other portion of the formation, the purple or black oxide being the prevailing ore of iron which stains these rocks in Shropshire.

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[1] The southern portion of this anticlinal is marked in the map accompanying the memoir of Dr. Buckland and Mr. Conybeare. (Geol. Trans. vol. i. pl. 38.)

All the organic remains, however, agree with those in the cliffs of the Teme at Ludlow, there being scarcely one characteristic Salopian specimen which is not to be found here. As this and some promontories on the other bank of the Usk are the most southern points in England, at which the Ludlow Rocks are well developed, it is highly important to observe their uniformity of structure, and also that the uppermost strata here pass with equal conformability into the Old Red Sandstone, as in Shropshire and Herefordshire, &c. The extreme northern point of this upper rock is at Clytha Pitch, where it is cut through by the high road from Monmouth to Abergavenny, and where the strata, dipping 10° or 12° to the south-west, are charged with many casts of fossils. There is not here the same clear junction with the Old Red Sandstone as at Usk Castle, the lower slopes of the hills being covered with gravel. Any transverse section of these hills, a mile or more to the south of Clytha Pitch, affords, however, clear evidences of the overlying succession. Thus, in proceeding from Ragland directly across the ridge to Trostrey Lodge, flaglike strata of Old Red Sandstone rise up at Rhiwlais and Tylochor, and dip from the underlying mass of the hill, which at Bettws is a yellowish thin-bedded sandstone, the equivalent of the Downton Castle freestone, p. 197. These beds are there distinctly underlaid by dull grey Ludlow Rock, in which many of the best known fossils abound, including numerous *Orthoceratites.* (See Pl. 36. f. 23.)

The chief interest in this group, is in the hilly tract upon the right bank of the Usk. Commencing with the ridge and church of Llanbadock, we trace with perfect precision the outline of the grey land, in marked contradistinction to the surrounding envelope of Old Red Sandstone, the Ludlow Rocks rising along the line of separation into a distinct chain of hills, of heights varying from 300 to 500 feet. At Llanbadock, the Upper Ludlow Rocks are arched, and plunge south-eastwards into a plain of Old Red Sandstone at angles of 60°; some of the lower strata which are strong bedded and calcareous, and of an indigo colour, clearly occupying the place of the Aymestry Limestone. The upper beds are full of the *Serpuloides longissima, Cypricardia amygdalina,* and other fossils. At Llangibby, the modern mansion stands upon the Old Red Sandstone, but the Ludlow Rocks ascend from beneath it into picturesque and wooded hills. The Darran, a rugged crag on the S.W., exposes many of the shelly beds, in some parts highly calcareous. Passing by Slovad's Wood, the same rocks expand over Maesmawr, and are completely developed in the Panta dingle, where the beds conforming to the quâ-quâ-versal dip of the central mass, are inclined to the west at an angle of 10°. This is perhaps the best point within the area of the Silurian group, where a clear succession is exhibited of all the strata, from the older formations which occupy the centre of the ellipse in Glasgoed and Prescoed Commons, to the Old Red Sandstone, and even to the carboniferous strata. Being within two miles of the edge of the great coal basin of South Wales, we may thus examine, within a distance of five or six miles, the representatives of all the strata between the productive coal and the Caradoc Sandstone. (See Section, Pl. 36, f. 23.) The Ludlow Rock, in this little gorge, is slightly calcareous and traversed by veins of pink calcareous spar, and in one part its beds are separated by a band of pure white, unctuous clay, like the "Walker's soap" of Salop and Hereford. (See p. 204.)

Fossils abound, including *Terebratula Wilsoni,* and some *corals,* while the beds beneath the hard stone are loaded with the *Asaphus caudatus*, *Productus depressus,* &c. The overlying strata, mounting into the hills above Llanfihangel, dip 20° west; and some of the highest beds, like those of Downton Castle, pass into the Old Red Sandstone, being yellowish, thinly laminated sandstones, and containing, together with the *Leptæna lata* and other Salopian fossils, the small orthoceratite of the junction beds in the Cwm Dwr, Caermaerthenshire. (See p. 181, & Pl. 34. f. 1.) The Lower Ludlow Rocks, on the right bank of the Usk, appear in great thickness in the escarpment of the

Llangibby Hills, particularly in the steep descent from the "high beech" to Prescoed, where the perishable mudstone is many hundred feet thick. The rocks of this formation occupy, on the whole, the highest hills of this Silurian tract, and, like those of Woolhope Valley, are excavated deeply at their escarpment, leaving a valley between them and the Wenlock Limestone, the next hard rock in descending order.

### "*Wenlock Limestone.*"

This limestone constitutes a low narrow zone, which circling in pretty regular curves for two or three miles in the southern portion of the tract folds over the Caradoc Sandstone of Prescoed Common, and dips at low angles to the east, south-east and south, beneath the Ludlow Rocks. After an interval in which the limestone is not distinctly traceable, it reappears in a very prominent ledge of about two miles in length, forming the eastern side of Glasgoed Common, along which it has been extensively quarried, the beds dipping to the west at angles of 8° and 10°, and passing under the Lower Ludlow Rock.

The limestone has the same characters as in Shropshire and Herefordshire. We perceive the same small concretionary nodules of impure limestone, here called "bowls" by the workmen, passing down into hardish, dull, earthy limestone, or calcareous grit, which sometimes alternates with courses of whitish yellow clay, and is underlaid by a subcrystalline encrinite limestone, thinly bedded in the upper but thickly in the lower part. In some places the strata composing the latter have a considerable thickness, and are occasionally mottled pink and greenish grey, in which cases they are undistinguishable from certain beds near (Easthope) Wenlock Edge. A fine section of the thick bedded grey limestone is exposed in the quarries of Cil-na-caya, the strata dipping 25° beneath the hills of Ludlow Rock, and containing many good fossils.

The lower shale is here clearly seen beneath the limestone, and weathers to the same light ashen colour as in Salop. The analogy with the Shropshire beds is completed, by finding many large concretions or "ball stones" ten and twelve feet thick, which swell out suddenly and throw off the strata either abruptly or in undulations, as shown in the figures (pp. 210 and 211), for which reason the workmen here term them the "old horses," meaning thereby, that the regular beds ride athwart them. In these "ball stones" the limestone is as crystalline as in Wenlock Edge, and contains many specimens of "chain" coral and other characteristic fossils.

### "*Caradoc Sandstone.*"

The Caradoc sandstone constitutes the nucleus of this tract, and occupying the dome-shaped mass of Prescoed Common, and the Hills of Cilfigan Park and Bryn Craig, dips on all sides beneath the Wenlock Limestone. *Tentaculites* and circular ferruginous casts of *crinoidal* stems, mark the surfaces of these thin bedded sandstones, in the same manner as on the eastern slopes of the Caradoc Hills. The escarpment of Bryn Craig explains clearly the relations of these beds: they there dip under the Wenlock Limestone of Glasgoed, a very thin mass of shale being interposed; whilst in the descent to the Tucking Mill, they are underlaid by a considerable thickness of shale, which weathers to a light colour and forms a cold soil. This shale is a local peculiarity in the mineral structure of the formation. It is, however, to be observed, that as they are here but slightly developed, they may represent those beds described at the base of the

Horderly Section (p. 220), and in a similar position near the south-western termination of the Malvern Hills, (p. 416). If they were found to contain the *Asaphus Buchii*, these beds would at once be considered Llandeilo flags[1]. The sandy flagstone is also visible in the high grounds of Cefn Isla, and is, apparently, thrown unconformably against the superior formations, in the ridge opposite the town of Usk; but there the quantity of wood and the absence of clear sections, coupled with reversed dips and dislocations, prevent accurate observation. In like manner a patch of impure limestone occurs in the hill above Rudor Farm, and seems to be associated rather with the Caradoc than the Wenlock formation, for it is thrown off upon the side of a low hill, in which are certain thin bedded sandstones. (See Map.)

On the whole this tract is of high geological interest. It is, indeed, the most southern point of Great Britain, where a passage from the Silurian Rocks into the Old Red Sandstone can be studied. Geologists, therefore, who cannot travel to those parts where the best types exist, may, it is hoped, be induced to visit a district which is also attractive, on account of its ruined castles and picturesque features[2].

Rising into concentric ridges, which are separated by deep intervening hollows and circle round a common centre, the strata are instructively laid open by many transverse breaks, and dip to nearly every point of the compass, at angles varying from 5° to 70°. There are also some good examples of the folding over of strata, particularly in the Ludlow Rocks above Llangibby, where small patches of Old Red Sandstone are produced in upland troughs, distant from the principal mass of the formation.

A great body of coarse gravel, which will be adverted to in subsequent chapters, is spread over the surrounding country, while no debris occurs within the central area; and hence it is inferred that this valley has been denuded by the same process as that of Woolhope (p. 436)[3].

In concluding the sketch of this group, it may be further observed, 1st. That the river Wye flows through a great fissure, *transverse* to the axis of the group. 2ndly. That this tract having been thrown up in close contiguity to the coal-basin of South Wales, its axis (from N.N.E. to S.S.W.), though parallel to the adjacent portion of the margin of the coal-field, is nearly at right angles to the major axis of the South Welsh coal basin, which trends from west and by north to east and by south.

[1] Though I examined these black shale beds in an excellent section (Bryn Craig) without detecting organic remains, the weather on that occasion was so unfavourable, that I should not be surprised if other observers were more fortunate.

[2] Ragland and Usk. The latter place is a favourite resort of the angler. (Read Sir Humphrey Davy's Salmonia, and do not pass by the sign of the Three Salmons, an excellent inn.)

[3] This observation applies only to the central part of the elevated tract, which dips from the common centre of Prescoed Common on the right bank of the Usk. The Hills of Trostrey and Clytha, and the higher plateaux of Ragland, Penrose, &c., are nearly as much obscured by gravel and even by heavy boulders, as the low grounds adjacent to the river. (See Map and concluding chapters.)

## *May Hill.*

*Prolongation of the axis of Woolhope by May Hill, to Purton and Tortworth in Gloucestershire.*

The Silurian ridge which forms the south-eastern termination of the valley of Woolhope, ranges by Oldbury Hill to the eastern side of Upton Bishop, exposing grey, incoherent and flaglike strata of Ludlow Rocks, flanked by Old Red Sandstone.

At Yeaton the beds dip 35° to the W.S.W., but to the south the line of elevation becoming less distinct, at Chibler's Hill they are inclined only 8° or 10° to E.N.E. Beyond Upper Tedgewood they are no longer traceable; for between Linton Wood and Queen's Wood, these Upper Silurian Rocks rise in dome-shaped masses from beneath the clays of the Old Red Sandstone. In Linton Wood, ferruginous sandstone overlies beds of earthy grey limestone, some of which are burnt for lime, and from their position and fossils are presumed to be the equivalent of the Aymestry Limestone. Light coloured sandstone, sometimes almost white and occasionally micaceous, generally constitutes the upper ledge of these rocks. Such beds are well seen at Clifford's Mine, in contact with the Old Red Sandstone. On Gorstey Common, one of the domes alluded to, are very extensive quarries, which show this sandstone passing down into a dark grey, sandy, argillaceous rock, with casts of some of the Ludlow shells, underlaid by two remarkably hard beds of calcareous grit, nearly one foot thick each, called "pitching stone" and "hone stone," which again are succeeded by fifteen or twenty feet of beds, sufficiently calcareous to have been formerly burnt for lime. Other quarries, north of the great road from Ross to Newent, expose grey, flaglike beds of genuine mudstone, with concretions of argillaceous limestone. Up to this point the Ludlow Rocks only are apparent, but in approaching May Hill we meet with two broken lines, along each of which masses of the Wenlock limestone have been thrown up; the one ranging by Aston Ingham being a simple band, the beds of which are in a vertical position, striking 15° east of south, and containing many characteristic shells and corals. The other, in Ristley Wood, includes several masses of the same rock thrown about with discordant strikes and inclinations, in one part dipping 45° east, in another 65° W.N.W. Some of these masses on the sides of Ristley Wood, are of the same red colour as the Wenlock limestone of Clencher's Mill near Ledbury, and are subordinate to shale, containing many small concretions of impure limestone. Near a spot called the New House Farm, where the strata are much contorted, and thrown into a south-easterly direction, it is a fine, crystalline, light grey limestone, highly charged with encrinites, corals and shells.

Advancing to the south-east, and ascending the arid elevation of May Hill[1], 965 feet above the sea, we find ourselves upon red-coloured Caradoc sandstone, filled with

[1] I recommend every traveller who may be near it to ascend May Hill, from the summit of which he will enjoy a panoramic view not inferior to any in Great Britain. The Severn, meandering through rich plains, is seen to expand into its magnificent estuary, landlocked by the Cotteswold, Mendip, Quantock and Devonian Hills; while to the N.E. and N.W., the rich and undulating expanse of the central counties, is beautifully contrasted with the sharp outline of the Malverns, and the sombre distant masses of the Welsh Mountains.

casts of characteristic shells, the beds being quite undistinguishable from those described in Shropshire. (See p. 216, *et seq.*)

The Caradoc sandstone of this hill, including its south-eastern prolongation, Huntley Hill, &c., throws off for some distance bands of younger Silurian strata on each side. On the north-eastern face, these strata prolonged from Ristley ridge, are spread over Rawtrings Wood near Huntley, folding round and covering the grit and sandstone of Plantation Hill. These are only thin courses of impure limestone and shale, with shells of the Wenlock shale, and they are best seen in the descent to Glass-house Green, where they are flanked on one side by the clays of the Old Red, and on another by the New Red Sandstone.

The ridges on the western face of the hill are the prolongations of the calcareous zone of Aston Ingham, which expanding as it approaches May Hill, exhibits, for three or four miles, a regular ascending order, from the underlying Caradoc Sandstone, through the Wenlock and Ludlow formations, to the Old Red Sandstone. This succession is so perfectly exhibited on the sides of each of the great roads which, traversing the central ridge, descend into the vale of Longhope on the west, that I specially invite attention to the section (Pl. 36. f. 13.) as exhibiting a good development of the Caradoc Sandstone, and particularly of its passage upwards into the Wenlock limestone, through argillaceous and calcareous strata of great thickness. These beds of passage between the sandstone and the shale, contain a large proportion of calcareous matter. Where the lower strata become flaglike, and consist of thin courses of impure limestone, they are the equivalents of the central limestone of Woolhope, and, therefore, the uppermost part of the Lower Silurian Rocks. All the overlying shale, filled in great measure with concretions of argillaceous limestone, must be classed with the Wenlock formation.

The Ludlow Rocks form a second ledge, in the descent from Hobbs to the valley of Longhope, where, although they only represent that formation in miniature, their upper portion is marked by the *Leptæna lata*, and other characteristic shells. A band of impure sandy limestone, charged with the *Terebratula Wilsoni*, and consequently the equivalent of the Aymestry limestone, occurs near the centre of the ridge.

In the transverse section from Dursley Cross to the valley of Longhope, the lower beds dip away from the nucleus of May Hill at angles of 45° and 50° to the W.S.W., the dip decreasing in the outer ledges, so that the Wenlock limestone is inclined 35°, and the Ludlow rocks only 20° towards the same point. (See Section, Pl. 36. f. 13.)

A parallel transverse section from Little London, at the side of Huntley Hill, to the valley of Longhope, across the end of Blaisdon Edge, shows the same succession, with still more instructive examples of the red beds of Caradoc sandstone, filled with casts of many distinguishing fossils. The ledge of Wenlock limestone can be followed with precision, standing out by itself with a valley on each side, just as in the Wenlock Edge or in the vale of Woolhope; the same soft shale having been similarly denuded. As in other places, these masses, after preserving a straight

course for a mile or more, are snapped through by transverse faults, and often change their directions. The high road to Ross passes through one of these breaks, on the north side of which the mass of limestone called "the Rock" is thrown over with great curvatures, dipping south, west and east; whilst on the south side, the thick-bedded limestone with "ball stones," and overlying small concretions, dips 40° west, or west-south-west. Near this disturbed spot, the few beds of Ludlow Rock which are visible, are unconformable to the Old Red Sandstone[1].

Another transverse fault is exhibited in the sides of the road leading from Little London to Mitchel Dean, where it passes through the limestone ridge of Blaisdon Edge, and the strata being broken off, are diverted from their south-easterly course, a little to the west of south. At the southern extremity of this ridge, is another and more deeply seated crack, through which the Longhope brook, after having defiled for some miles along the outer zone of the Silurian Rocks, is suddenly deflected, and escapes through the gorge to the Severn. From this point, the whole system gradually tapers away into one low ridge, on the eastern side of Flaxley Park.

Besides the shelly beds, principally reddish sandstone of the Caradoc formation, the hills of May and Huntley contain still lower masses of very hard grit, some of which are singularly convoluted and of peculiar structure. These may be well observed on the sides of the high road between Huntley and Dursley Cross. (See section, Pl. 36. f. 13.) In proceeding from the village of Huntley, the cuts on the north side of the road have laid bare these grits, which burst out abruptly from the plain of New Red Sandstone in almost vertical strata, sometimes indeed converging round a nucleus, and reminding the observer of the concretionary quartzose grits of the Cambrian rocks. Occasionally they have almost a trappean aspect. Other hillocks, on the left of the road, consist of hard dark grey sandstone and purple schist, folding round compact sandstone and fine-grained greenish grit. The axis of these hillocks points 12° west of north, and the mantling strata dip under coarse ferruginous grits almost conglomerates. Although the latter are clearly surmounted by red sandstone containing Caradoc shells, yet as I could not observe a conformable junction, I am not certain that the underlying masses strictly belong to the Lower Silurian Rocks.

In following the axis of this ridge to the south, through the centre of Huntley Hill, it is interesting to observe the termination of the Silurian rocks at Flaxley, where they are reduced to a sharp point of Ludlow rock, not exceeding thirty paces in width, and cut through by the high road from Mitchel Dean and Longhope to Gloucester and Newnham. These are flaglike, greenish grey beds, in parts calcareous, probably belonging to about the middle part of the Ludlow formation, containing imperfect casts of fossils, the strike being 10° or 12° to the west of north, as in the central mass of May and Huntley Hills, and the dip 50° to 60° to the east. (See Map and Pl. 36. f. 14.) This inclination is in an opposite direction to that of the Silurian strata of Blaisdon Edge and Flaxley Park, thus marking the continuance of a true anticlinal; whilst the line of springs and ponds between the park and this detached hillock, marks another

[1] It was doubtless the appearance at this spot which lead Mr. Weaver to suppose, that the transition rocks were *generally* unconformable to the Old Red Sandstone, a conclusion it was natural he should adopt, (as will presently be shown) from the stronger evidences of their discordance exhibited at Tortworth, the district he had selected as a type. (Geol. Trans., vol. i. p. 354. Pl. 29, f. 4.)

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*View from Tortworth Terrace, looking towards May Hill and the Malverns, from a sketch by Mrs. Murchison.*

## CHAPTER XXXIV.

### ON THE ROCKS OF THE TORTWORTH DISTRICT (GLOUCESTERSHIRE).

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*General succession of strata, from the Inferior Oolite to the Lower Silurian Rocks.—Inferior Oolite and Lias.—New Red Sandstone and Dolomitic Conglomerate.—Coal Measures (unconformable to the overlying strata).—Carboniferous Limestone.—Old Red Sandstone (peculiarities of).—Silurian System.—Small developments of Ludlow and Wenlock formations.—Caradoc Sandstone clearly exhibited.—Trap Rocks all of intrusive character.—Altered and dislocated deposits.—Strata elevated and thrown into anticlinal forms by the outburst of trap.* (See Map and Pl. 36. figs. 16 to 22 inclusive.)

PERHAPS no district of similar extent in Great Britain presents so many different geological formations as the picturesque tract around Tortworth in Gloucestershire. This district was first brought into notice by the researches of the Rev. Dr. Cooke, Rector of the parish[1]. It next acquired a scientific repute through the memoir of

[1] It is delightful to trace in the MS. maps and drawings of the venerable Rector of Tortworth (the intimate friend of many of our early observers) the impress of much originality of thought and sound geological views, long before this district was described by geologists. If country clergymen in general, occupied a few of their leisure hours in acquiring a knowledge of the natural history of their neighbourhood, with as much zeal as Dr. Cooke, the task of those who endeavour to group and generalize facts would indeed be lightened. I speak with a grateful recollection of the kind assistance afforded me.

Mr. Weaver[1] and that of MM. Buckland and Conybeare[2]. It was not, however, in the power of any geologist at that day to describe correctly the order and succession of the rocks, now called Silurian, from the diminutive and distorted features they display in this district. For although these rocks constitute a considerable portion of the area around Tortworth, yet they are in many parts so ill exhibited, assume so peculiar a mineral structure, and are in general so imperfectly divided into the formations composing the Silurian System, that it would be a hopeless task for any geologist, even at the present day, who should here commence his observations on "Transition Rocks," clearly to unravel their relations. Nature, indeed, has here presented us with only an obscure miniature of those formations, the larger portraits of which must be viewed in other districts.

The Silurian rocks of Tortworth, it will be observed, lie in the direct prolongation of those which we have traced from the valley of Woolhope in Herefordshire, through May and Huntley Hills, and which, subsiding beneath the Old Red Sandstone at Flaxley, reappear on the right bank of the Severn at one point only, viz., Aram. On the left bank they rise "en masse" at Purton passage, as represented in the foreground of the vignette p. 446, and expanding from that point stretch across by Berkeley, occupying this part of Gloucestershire.

Before, however, I proceed to describe these older rocks, I may, on this occasion, be permitted to deviate from the method hitherto followed in this work, and give first a general sketch of the structure of the whole tract, offering a few words upon each of the overlying formations by which it is so remarkably diversified. To have repeatedly carried the reader from other parts of the work to this small tract, whenever allusion was made to any one of the numerous rocks of which it is composed, would have prevented the attainment of a clear notion of its complicated structure.

Taking the church of Tortworth as a centre, we see by the map, that this district is made up of nearly every sedimentary deposit, from the Inferior Oolite to the Lower Silurian rocks. The relations of all the strata, however, as might be expected in so small a tract, are not clearly presented, still less the transitions from one group to another. The very collocation of such a number of beds of different ages, within so circumscribed a space, is at once proof, that many of them must lie in abrupt and truncated positions, which it requires some experience and considerable patience to detect and explain. That such is the case at Tortworth, those who have perused either the memoir of Mr. Weaver[1], or that of Messrs. Buckland and Conybeare[2], will be convinced; while few modern observers can visit the spot without perceiving, that as rocks of igneous origin have penetrated through it at many points, so they have doubtless largely contributed to produce the disruptions and denudations which belong to the district. I

[1] Geological Transactions, vol. i. p. 317. [2] Geological Transactions, vol. i. p. 210.

will first, therefore, give a short sketch of the overlying formations, showing where they pass into each other, and where they are obscured or broken; and then point out the range and distribution of the Silurian deposits, concluding with a few words upon the effects due to the intrusion of the trap rocks.

### *Inferior Oolite.*

The district is flanked upon the east by a succession of bold tabular promontories, the most prominent being the trigonometrical station at Stinchcombe, north of Wotton-under-Edge, and having a height of 800 to 900 feet above the level of the sea. The summits of these hills consist of the inferior oolite, which constitutes, as before stated, the escarpment ranging thence to the eastward of Cheltenham, constituting the chief mass of the Cotteswold Hills, the strata dipping very slightly to the east and south-east, p. 14. The well-known characters of the various beds constituting this formation must be sought in other works. The Avon, the chief of the little streams which water the Tortworth tract, rises at the foot of one of these oolite hills to the south of Wotton-under-Edge.

### *Lias.*

This great formation which constitutes the base of the whole oolitic system extends over a great part of the plain and undulating country between the older rocks of Berkeley and Tortworth and the inferior oolite of the hills. Through the labours of Mr. Lonsdale, who has laid down the course and outline of this and the overlying oolitic formations in Gloucestershire, we first learned that it consists here of two subdivisions, the marlstone and lower lias. The first of these is chiefly made up of yellow and ochraceous sandstone, passing into blue calcareous grits, and charged with abundance of *Gryphæa gigantea, Pecten æquivalvis,* and other fossils. It rises, for the most part, to a height of several hundred feet on the sides of the oolite hills, and is separated from the inferior oolite by only a very narrow zone of upper lias shale. This marlstone is exposed through all the deep recesses which penetrate the oolite hills, and advances at some points far into the Vale of Gloucester. (See Map.) Thus at Newnham windmill, situated on one of the sloping terraces below the oolite of Stinchcombe Hill, and overlooking the lower lias of the vale of the Severn, it is largely quarried as a road stone and transported to distant parts of the Berkeley district. In the older classifications of British rocks, this deposit (here, perhaps, not less than 100 feet thick) is considered to be the base of the inferior oolite, a place in which it can no longer be recognized, since not only has it a community of fossil character with the other parts of the lias formation, but it is also overlaid by an upper lias shale or marl, which completely separates it from the inferior oolite. (See p. 16.) The lower lias, in its usual forms, spreads out from beneath the terraces of marlstone, and extends to the edge of the older rocks, in some places exhibiting towards its base, a conformable passage into the New Red Sandstone, in others abutting or resting abruptly on Old Red Sandstone and Silurian rocks. Passages from the lias into the underlying New Red Sandstone can be observed in the sides of Whitcliffe Park Hills, south of Berkeley; but the clearest and best instances are to the east of Wickwar, near Sturt Bridge, on the sides of the new road ascending to Wotton. In the same neighbourhood I have noticed at several points the well-known *bone bed,* subordinate to the lowest layers of black shivery shale of this formation, and immediately sur-

mounting the green and red marls of the New Red Sandstone. In an insulated fork of lias, a prong of which advances to the south of Charfield Church, I found slabs of this bed highly charged with Saurian bones, coprolites, &c.; and Dr. Cooke informs me that he had previously collected similar remains in the lias overlying the red marl under Wotton.

The great mass of lias in the Vale of Gloucester is in general so flat, and so much covered by the fine debris of the oolite escarpment, that any estimate of the destruction it has undergone, can be formed only by considering the depth to which the vale has been denuded; but when we examine the sides of the broken ground of older rocks, of which the Tortworth district is composed, we obtain some measure of the amount of this destruction, by finding small patches of the lias adhering at different levels, in one place to the carboniferous limestone, in another to the dolomitic conglomerate, frequently in patches so minute that it is barely possible to lay them down even upon the sheets of the Ordnance Survey. Three of these alone are indicated in the annexed map[1].

## *New Red Sandstone.*

The upper and central members of the system of New Red Sandstone, so largely expanded in other parts of the kingdom, has been correctly defined in this neighbourhood by Mr. Weaver, as consisting chiefly of red clay and marl, and as being specially distinguished by the presence of strontian, a mineral which the same author has pointed out as occurring also in rocks of different ages in the Tortworth district. As the passage of the red marl into the lias is here well exposed, so also on the sides of the road east of Wickwar is a perfect transition in descending order of these marly beds into beds of sandstone, and thence into beds of dolomitic conglomerate.

## *"Magnesian Limestone" = "Dolomitic Conglomerate[2]."*

The rocks forming the base of the New Red Sandstone in the south-west of England have been

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[1] Dr. Cooke pointed out to me other small patches of lias near Tortworth. For an acquaintance with one of them near Thornbury, I am indebted to Mr. Fry, of the Round Tower on Olveston Down.

Owing to one of the most modern changes of the surface, a well known locality of lias is no longer visible, and collectors can never more repair to the shore at Purton Passage to gather those lias fossils which ornament so many museums. The process of encouraging the mud of the Severn to accumulate upon lines of pile and osier, has been so effectually practised by Lord Segrave, that the fossil beds which appeared as ledges at each ebb tide, have been buried under slimy sediment, which by an additional embankment will at no very distant day pass under the plough of the husbandman. It was with infinite delight, therefore, that I found this mud had not yet extended so far as to obscure the instructive arch of *Silurian Rocks,* which is still partially seen at low water rising from beneath the overlying deposits and forms the foreground of the vignette, p. 446.

[2] The term "Dolomitic Conglomerate" was first applied to this rock by Messrs. Buckland and Conybeare, at the suggestion of Mr. Warburton, and on the authority of Von Buch. "That definite triple salt, the carbonate of lime and magnesia, when found native in a state of purity and associated with primitive (*or altered*) rocks, has received the name of dolomite; and it is the same salt, intimately but mechanically blended with iron or bitumen, or carbonate of lime, which in beds forming part of our New Red System have been called magnesian limestone. It appears to us desirable to use but one appellation for substances not essentially differing in chemical constitution."—Geol. Trans., N. S., vol. i. p. 212 *note.*

described by several geologists[1], and in this tract especially by Mr. Weaver, whose account of their structure is so good that I cannot do better than quote it. "They are composed principally of rounded and angular fragments of limestone and sandstone, sometimes exceeding the size of the head, with fragments also of hornstone and quartz: these are cemented by a calcareous paste, which is frequently of a marly nature, or a common carbonate of lime, either of an earthy or compact structure; but in some quarters, as in the Vale of Thornbury, the cement is generally magnesian, and through all the varieties sandy particles are more or less distributed. The compound abounds in cavities which are frequently lined with crystals of calcareous spar and quartz, and sometimes also with sulphate of strontian."

The exact range of the conglomerate and magnesian limestone is given in the accompanying map. It generally forms an irregular broken fringe, hanging upon the flanks of the older rocks, sometimes consisting of a very coarse conglomerate of considerable thickness, which rests either on the carboniferous limestone or Old Red Sandstone, the fragments in each case being made up respectively of the detritus of these rocks. On the sides of the new Bristol road, as it descends to Thornbury, the following section of the passage of this conglomerate into limestone has been recently exposed.

*a.* Yellow sandy beds, covered by red detritus. *b.* Impure limestone, about one foot thick. *c.* Courses of limestone, two to three inches thick, alternating with yellow sands. *d.* Yellow sandstone, partly calcareous. *e.* Dolomitic conglomerate resting on carboniferous limestone, and made up of large fragments of that rock.

To the east of Thornbury the dolomitic conglomerate rests directly on the coarse conglomerate of the Old Red Sandstone, the beds of the older being almost as horizontal as those of the newer conglomerate. It is again seen at the same inclination and in conformable apposition to flaglike beds of the Old Red Sandstone to the south of Kington. The reader wishing to acquire more copious information respecting this conglomerate, as it expands into the districts around Bristol and in the Mendip Hills, must consult the various memoirs in the Geological Transactions in which it is described. My principal object is to direct attention to the different relation of the conglomerate to the older rocks in the south-west of England, and in Shropshire, Staffordshire, and Worcestershire. In the former district, it has just been shown to lie unconformably upon the coal measures and more ancient strata; while in the latter it was proved in previous chapters to pass down gradually into the true coal measures, through the Lower New Red Sandstone, which being almost entirely absent in this region, accounts to us for the unconformability between these two deposits.

It is, therefore, essential to remind the reader that the great break marked by Messrs. Buckland and Conybeare at the base of the dolomitic conglomerate, and which is so extensively and clearly displayed in the south-west of England, must be considered as only a partial phenomenon; for it has been clearly ascertained, that the same action which there broke off the connecting links between the New Red System and the coal measures, did not extend into the central counties; on the contrary, we have seen that all the intermediate strata have been there deposited in regular and unbroken succession. (See p. 46 *et seq.* and the following chapter.)

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[1] Geol. Trans., Old Series, vol. iv., in memoirs by Dr. Knight, Mr. Warburton, and Mr. Gilby, and also by Messrs. Buckland and Conybeare in the memoir before mentioned.

## *Coal Measures and Millstone Grit.*

On these formations it is unnecessary to dwell, as they occupy so small a portion of the annexed map and have been fully described by other authors. The same two beds of coal mentioned by Mr. Weaver are still wrought at Cromhall Heath, though further upon the dip, and consequently at greater depths. It is, however, desirable to point attention to the underlying strata of grit and shale with courses of impure limestone, which support this coal-field, because they resemble beds of similar age at Oswestry (p. 144). The general colour of these underlying and unproductive coal measures is *red*, a colour which prevails in rocks of this age at Oswestry, Lilleshall, &c. As we proceed we shall point out, that this colour also characterizes the surface of two-thirds of the rock formations of the Tortworth district. Messrs. Buckland and Conybeare have considered all these red and white grits, with courses of red shale and impure limestone, as equivalents of the upper limestone shale beneath the millstone grit. Besides, however, the true upper limestone shale of these authors, a detailed section of which, by Mr. Lonsdale, is given (p. 158), there are at Cromhall quartzose conglomerates and reddish grits, which as they immediately pass under the coal-bearing strata and overlie the calcareous formation, may be grouped with the millstone grit. (Pl. 36. f. 21.)

## *Carboniferous or Mountain Limestone.*

To the south of Tortworth, this formation is thrown up in a horse-shoe outline, rising from beneath the millstone grit and coal measures of Cromhall into rocky masses, for the most part well wooded. It is unnecessary to describe this well-known limestone, or to say that it is in many parts charged with its usual organic remains. The dislocations, however, to which it has been subjected are worthy of notice. So far from presenting an uniform and unbroken band, as might be supposed from its appearance when laid down upon a small scale, it is broken into a number of distinct masses by transverse dislocations, which have the strata in each mass often dipping at different angles and frequently in opposite directions; such phenomena are observable along the ridge from Tortworth Lodge to Tytherington: and in the rocky grounds south of Cromhall Park, the limestone is so dislocated as to form sometimes double troughs dipping E.S.E. and W.N.W. at angles of 35° and 40°, while near Tytherington it rises like a wall from beneath the Cromhall coal-field. In this range, its upper part contains a subordinate band of reddish sandstone, the firestone of the country people. In the map a considerable extension is given to the limestone south-west of the Tortworth and Cromhall tract. At Littleton-on-Severn, where it is the fundamental rock on which the dolomitic conglomerate, New Red Sandstone, and lias repose, the limestone becomes very sandy, passing into chert, and sometimes weathering to a yellow colour, with druses containing decomposed magnesian limestone. There can be little doubt that much of the adjacent dolomitic conglomerate, which in its aspect and matrix so much resembles this limestone, has been derived from this source. The prevailing fossils at Littleton are *Encrinites*, and the *Spirifer trigonalis* (Sow.).

Besides the ordinary characters and prevailing fossils of the carboniferous limestone with which this tract abounds, it also presents certain beds of *transition* between the limestone and the Old Red Sandstone, (the lower limestone shale of Buckland and Conybeare,) to which special attention must be paid, since they so much resemble

Caradoc Sandstone, that without a clear order of superposition and close examination of the organic remains, even practised observers might be misled. These beds consist of yellowish and dull brownish red sandstone, alternating with shale and impure limestone, the surfaces of the former being frequently impressed with the circular forms of crinoidal stems, resembling the casts so common in the Caradoc formation. In Monmouthshire, particularly to the west of Chepstow, I have already noticed a large development of these beds. (p. 160, and Pl. 36. f. 24.) A small boss of them has recently been exposed near the Ship Inn, at Abbey Land, on the sides of the high road from Bristol to Gloucester, the organic remains from whence having been examined by Mr. Stutchbury, prove to consist of the palates of the same species of fishes which characterize the bottom beds of the carboniferous limestone in other places; viz. *Psammodus linearis*, *P. lævissimus*, &c., together with bodies supposed to be *Coprolites*, and the *Pileopsis angustus*, Phill., a shell of the carboniferous system. These beds are not, however, peculiar to Gloucester or Monmouth, for they are exposed at various points around the great South Welsh coal-field and in Pembrokeshire[1]. (See p. 384.)

### *Old Red Sandstone.*

Succeeding to the carboniferous limestone, the Old Red Sandstone of Tortworth presents peculiarities of structure, which are not found in the chief range of this system. The upper beds, instead of being conglomerates, consist of finely-grained, thin flagstones of white and whitish grey colours. These are seen in the elevated platform of Tortworth Green, where they dip distinctly under the carboniferous limestone, and pass down into red sandstone and argillaceous red and green marls of considerable thickness. This upper division is underlaid by coarse, quartzose conglomerate and red sandstone. Sections made in remote parts of the district, six and seven miles from each other, either in ascending from Falfield to Tortworth, from Thornbury to Milbury Heath (where some of the best quarries are seen), or from Kington west of Thornbury to Mumbleys Plat, exhibit the same succession and persistency of the conglomerate in the central and even low part of the formation.

An enormous thickness of red and green argillaceous marl is clearly indicated by the sections at Gatcombe and Purton, on the right bank of the Severn. We there see, red, green, and white-spotted marls, quite undistinguishable from those of the New Red Sandstone, with a few strong bands of dark red micaceous sandstone. The large development of these argillaceous marls of the Old Red, renders it most difficult to draw a line of separation, in any geological map, between them and beds of similar composition in the New Red, wherever the *marls* of the two systems are brought

[1] See also the detailed sections in the memoir of Messrs. Buckland and Conybeare, by Mr. De la Beche, Mr. Cumberland, Dr. Bright, &c., Geol. Trans., vol. i. p. 240.

together, as along the western flank of the Tortworth tract; for while we trace the persistence of the Old Red Sandstone from Berkeley to the south, and confidently assert that it forms the substratum of that portion of the district, we cannot definitely mark its boundary, though we know that the red and green marls of Whitecliff Park and Sunday Hill, from their conformable passage into the lias, must belong to the New Red System. Whenever the sandstone of the older formation appears, or that the face of the rock is highly inclined, (a feature not observed in the New Red of this tract,) the difficulty vanishes, but unluckily such good evidences are exceedingly rare, and the Old Red Sandstone is in many situations quite as little inclined as any of the overlying formations. At Thornbury and at Kington the conglomerates, hard sandstone and grits of the Old Red dip only 5°, 10° and 12°. The day, indeed, has now passed by, for estimating the age of sedimentary deposits by the angle of inclination in which their strata are placed, since we know that in disturbed regions the cretaceous and even the tertiary strata are often vertical.

## *Silurian System.*

Though occupying a considerable area, the rocks composing the Silurian System are clearly exhibited at only a very few points. Over a large portion of this area, their exact places are not easily assigned, owing to their small development and the great extent to which they have been denuded, and it was not till a fourth visit, that I was able to determine their precise extent and range. One of the chief difficulties, already alluded to, lies in the red colour which prevails over two thirds of the district, whether composed of the New Red, Carboniferous, Old Red, or Silurian Systems.

### *Ludlow Rock.*

The best representatives of the Ludlow rock which I have detected are the beds seen at low water on the west bank of the Severn, at Purton Passage, where rising in a dome-like form, and dipping beneath the Old Red Sandstone of the opposite bank of the river, they are partially overlaid by that rock at the Ferry-house. (See wood-cut, p. 446.) The section (Pl. 36. f. 17.) also represents the succession of the Silurian strata at their point of emergence on the Severn, where they dip away on three sides at angles of 15° to 20°. The uppermost beds are somewhat obscured by mud, and the detritus already alluded to as having entirely covered the adjacent fossil beds of the lias. These upper beds or Ludlow rocks are of dark greenish grey colour, somewhat micaceous, and contain ***Leptæna lata, Orthis unguis,*** &c. Beneath them is a very thin course of impure limestone, containing ***Terebratula Wilsoni,*** and representing the Aymestry limestone. Other beds of a mudstone character succeed, with occasionally flattened spheroidal concretions; and these strata, the equivalent of the Lower Ludlow, pass down into shelly calcareous beds, representing the Wenlock limestone. This succession is laid bare on the shelving shore, between low and high water marks, in a number of thin-bedded ledges which wrap over each other, the highest stratum

or Upper Ludlow rock, being flanked by greenish micaceous tilestone and red marl of the Old Red Sandstone, and also by very hard greenish grit of the same formation. These beds are more or less coated with red oxide of iron. They are much jointed; the dominant joints ranging from S.S.E. to N.N.W. are traversed by others, occasioning these flaglike strata to split into a number of dice-shaped and rhombic forms.

With the exception of these beds at Purton, the only other evidence of the existence of what may be termed Ludlow rock, is at the Horse-shoe farm, below the north-eastern end of Milbury Heath, and consequently at the other extremity of the district. A few beds there contain some of the fossils, particularly *Cypricardia amygdalina*, and pass conformably into the overlying Old Red Sandstone, and downwards into beds with *Asaphus caudatus*, &c. After all, this Silurian formation is so very feebly exhibited in the Tortworth tract, and offers such slight lithological analogies to the best types, that without a long acquaintance with it in other districts, its recognition would be impracticable.

### *Wenlock Limestone.*

The Ludlow rock, at Purton, is underlaid by calcareous beds containing masses of corals and shells, among the latter of which is the *Productus depressus* together with many *Orthocerata*. From the fossils I conclude, that these beds represent the Wenlock limestone, of the existence of which there is abundant evidence in the south-western branch of the Silurian fork, which clasps round the Old Red Sandstone of Tortworth. Thus, we see this limestone commencing at Skeays Grove, near Falfield Green (quarries long abandoned), whence it extends in a separate narrow ridge by Falfield Mill to Brinmarsh, and afterwards sweeps round in a low, circular, dome-like form to Whitfield, where it dips outwards, passing on all sides under the overlying formations. For a short distance, near Falfield, this ridge is double, the upper portion being seen in Barber's quarry. The best section of the Wenlock limestone, particularly the lower part, is at Falfield windmill, where it is made up of the following beds in descending order:

1. Rubbly red, sandy, calcareous beds.
2. Thin, irregularly bedded, almost lenticular masses of purple and grey limestone, passing down into ash-coloured shale, with very thin courses of greyish blue limestone, the shale being loaded with many of the *corals* and *encrinites* peculiar to the Wenlock limestone, and small mollusks, such as the small *Spirifer radiatus*, of Dudley; the *Orthis canalis*, so common at Woolhope and many other places.
3. Purple and grey strong-bedded limestone, 20 to 30 feet thick, highly charged with *encrinites*, and the beds separated by courses of red shale.
4. Red and green schistose beds passing down into hard purple sandstone and grit.

The beds dip 45° to the east. They present in their red colour and general aspect, as well as in their fossils, a striking analogy to other beds of this age at Clencher's Mill, near Ledbury, p. 413. Dr. Cooke and Mr. Weaver have further collected in them the *Calymene Blumenbachii*, *Asaphus caudatus*, and other fossils.

At Whitfield quarries, where the same calcareous beds rise in a low dome, there are also many fossils. In the upper part, the rock consists of irregular concretions of impure grey limestone, with purple and whitish green marls, passing down into finely laminated, ashen-green and deep-red slaty marl, with irregular thin courses and concretions of strontian; next, flaglike sandstone, in beds of two to three inches. The lowest part consists of thick-bedded encrinite limestone, of purple and grey colours, containing corals and shells and passing down into slaty shale, &c. These calcareous beds are here about 15 feet thick, and uniformly rest upon the sandstone and shale of the Caradoc formation.

### *Caradoc Sandstone.*

The Caradoc sandstone forms the great mass of the Silurian rocks of the Tortworth tract; for while the overlying formations are miniature representatives of their types in other parts, the lower sandstone, associated with much red shale, covers an extensive area. Rising from beneath the upper strata at Purton, it first occupies a ridge in Scotts Hill, and advancing towards Tortworth, expands over the flat denudations of Halmore and Breadstone Green, and passing to the east of Berkeley, in unconformable juxtaposition to the Old Red Sandstone, occupies an area about three miles in width at Woodford Hill, Stone and Michaelwood Chace, whence the formation is projected to the S.S.E. and S.S.W. in two narrow bands, the eastern of which supports the limestone of Falfield and Whitfield. In many parts of this district the sandstone is so subordinate to the shale, that the deposit is familiarly known among the country people as "the clays," and where these abound, and the surface has been much denuded, as is the case at Berkeley Heath and Halmore Green, it is difficult to define the subsoil of Silurian rock, from that of the Old Red Sandstone or even of the lias. There are, however, certain helps by which the place of the Silurian Rock can be ascertained; such as the occasional sinking of a well, and by the deep ruts bringing up to the surface fragments of the thinly laminated beds, usually containing casts of characteristic fossils. To an eye practised in the district, the mere lithological structure of these beds is very dissimilar from that of any of the surrounding and overlying formations; the minuteness of the grains, the fine dissemination and intimate admixture of very small scales of mica, being alone sufficient to mark them. There are, besides, many clear sections of this formation, on the southern edge of Michaelwood Chace, on both banks of the Avon near Damory Mill, and at Stone; particularly on the sides of the Bristol road, near the Fox public-house. The sandstone and associated shale seem to contain a large portion of the oxide of iron, and consequently are as red in colour as any of the overlying groups. In colour, indeed, they present an exact parallel to many masses of the Caradoc sandstone of Salop, and are also perfectly undistinguishable from those of May Hill, many portions of which might (in the absence of shells) be mistaken for either New or Old Red Sandstone. The sandstone is sometimes very compact, and the beds vary in thickness from two to ten inches, whilst the shale is constantly in that state which by most observers would be termed slate marl. There is one thick bed of hard grit, used as building-stone in Michaelwood Chace.

The strata are inclined at all angles and in various directions, but generally they dip beneath the overlying formations south of Tortworth. The exceptions are found near masses of trap rock or along lines of fracture west of Stone, where beds of this age are thrown into unconformable contact with the Old Red Sandstone, dipping 70° west; or again near Falfield where they are raised from beneath the limestone in domes or arches,

so small, indeed, that it is only by occasional cuts and improvements in the roads that they can be detected[1].

Of the fossils of this formation, the *Pentamerus lævis* is perhaps most abundant, but others are scarcely less frequent, such as the ornamented small Trilobite (*Trinucleus Caractaci*), the *Tentaculites* of Schlotheim, as well as those *corals* which have been cited as so abundant at May Hill, and in Shropshire. The round impressions of encrinital joints scattered over the faces of the stone constitute one of the best empirical tests of this sandstone. The application of this proof, however, must be made with care, for there are rare examples of such impressions in the Ludlow and superior rocks. Their profusion, however, in the Lower Silurian rocks is very striking.

On reference to the description of the organic remains it will be seen that many have been figured from this district; but it is not pretended that the list comprehends all the fossils of this interesting tract; for as soon as a sufficiency of specimens were acquired for the identification of the respective strata, attention was directed to other points illustrating the general object of this work.

### *Trap Rocks.*

Having thus, from an acquaintance with similar deposits in other tracts, been able to convey to the reader a sketch of the succession of the stratified masses, exhibited at certain points in this district, I now proceed to offer a few remarks on the intrusive rocks which are associated with these deposits.

The trap rocks rise to the surface amid the Silurian strata, and repeated examination has convinced me, that they have everywhere been forcibly intruded into the latter. Though this view is opposed to that of the author who first described this district, it is supported not only by the recorded opinion of Messrs. Buckland and Conybeare, but also by that of nearly every geologist with whom I am acquainted, who has visited these localities. In their forms, arrangement, and relations to the associated strata, the trap rocks of Tortworth are entirely unlike any of those stratified traps which have been described in this volume, and which alternate so equably and conformably with the strata containing shells, as to afford sufficient evidence of having been evolved during the accumulation of the marine deposits. (pp. 269 *et seq.* 325 *et seq.*) On the contrary, these Tortworth trap rocks, whether viewed upon the natural surface, or in any of the numerous quarries in which they have been laid open, consist almost exclusively of amorphous masses, of irregular shape and unequal thickness,

[1] A recent widening of the road from Falfield to Tortworth, made by Dr. Cooke, exposed one of these little arches of sandy grit and slaty marl, rising from beneath the adjoining beds of Wenlock limestone. This evidence, however, was speedily obliterated by the building of a wall. Geodes of sulphate of strontian occurred in this section. Their presence in the New Red Sandstone has been previously noticed.

which protrude through and dislocate the overlying strata; sometimes throwing them off in discordant directions, at other times enveloping their fractured and dismembered portions within the masses of the trap. But while I differ from Mr. Weaver in my opinion of the origin of these rocks, I have sincere pleasure in quoting his lucid mineralogical description of them.

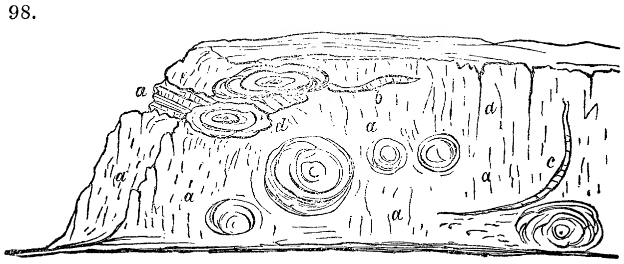
"The trap is of a very variable character in different quarters, consisting of granular and compact greenstone (the former seldom appearing of a distinctly crystallized structure), with occasionally disseminated portions of hornblende or augite, sometimes, though very rarely, graduating into basalt, of granular and compact felspar, of claystone and amygdaloid, all of which, being mutually intermixed, frequently interchange characters and pass into each other; and hence the shades of colour are never constant in any considerable portion of the mass, but fluctuate from black to green, red, brown and grey, the predominant colours being reddish brown and grey. The rock sometimes, also, though very seldom, assumes a porphyritic appearance, thinly scattered acicular crystals of glassy felspar occurring in its substance; but in general the common aspect of the trap may be said to be that of a compact rather than of a crystalline or even subcrystalline production, and where stealitic matter prevails, it is of a loose consistence, friable and earthy. It frequently contains compressed ovoidal and spheroidal nodules and kernels of chlorite, green earth, calcareous spar, brown spar and quartz, also balls of chalcedony and agate, the internal cavities of which are sometimes lined with crystals of amethyst; and when the more perishable ingredients are removed by decomposition they leave empty cavities, whence the rock acquires a vesicular and scorious aspect. Sulphate of strontian, sulphate of barytes, and prehnite, appear more rarely in the trap; which sometimes also includes portions approaching to compact brown iron stone, and brown jasper. Veins, composed of carbonate of lime and brown spar, either pure or mixed with trap and chloritic and steatitic laminæ, not unfrequently traverse the rock, occupying the cross fissures, which in some places divide it into cuboidal and other quadrangular concretions. These concretions sometimes exhibit a tendency to exfoliation, disclosing concentric lamellar layers that surround a spherical nucleus. The structure of the same mass of trap varies much in the course of its extent; it is most frequently amorphous, or irregularly divided by fissures; but when adjacent to the interstratified beds of sandstone, slate clay, and limestone, a faint tendency toward a corresponding division into strata may be partially observed; while in some other quarters, thin strata, from two to four inches thick, may be casually remarked, singularly contorted and inflected, yet subdivided by cross joints into rhomboidal prismatic concretions." (Geol. Trans. vol. i. p. 326.)

To this lithological description I have only to add the occasional presence of serpentine, which in their films (specially seen in the great quarries of Damory Mill), cover the faces of many of the bulging concretions, particularly near their points of contact with the Caradoc Sandstone. This phenomenon, it will be recollected, has been pointed out in various other localities under similar conditions, and notably in that case where the old Radnor trap rocks, (p. 320.), burst through limestone and sandstone of the Silurian System.

But to determine the essential question, whether the trap rocks of this district have been formed contemporaneously with, or posteriorly to, the strata with which they are intermingled? The points at which these rocks appear at the surface, are Middle Mill

and Woodford Green, (Horsely Quarry,) Michaelwood Chace, particularly on the bank of the little river Avon, near Damory Mill; on the left bank of that river, another line extending from Daniel's Wood, by Crockley's, to Avening Green; and, lastly, there are two bands more or less parallel to each other in Charfield Green. From the apparent conformability of one of these masses in Charfield Green to the associated strata, and from the presence of organic remains in the trap itself, Mr. Weaver has founded his best argument on the contemporaneous origin of the whole. When, however, narrowly examined, I conceive that this evidence itself demonstrates irresistibly the posterior intrusion of the trap. The band in question, if followed from the open quarries in Charfield Green, across the high road to Cullimore's Farm on the north, is seen to have a very variable thickness, and so far from being a regular bed, is found to have a most jagged and unequal surface. In one point, it is true, the igneous matter appears, though for a very short distance, as if it dipped conformably with the associated strata of sandstone; but this is soon ascertained to be nothing more than accident, for in pursuing its course, the trap again breaks out, throwing off the stratified deposits both to the south-west and west, and on reaching Cullimore's, the last point to the northward where this band is visible, we find distinct proofs of its posterior intrusion.

98.




This little wood-cut represents the vertical face of one portion of the quarry. In a depth of about fourteen feet which is exposed, there is not the trace of a bed, but we have before us a confused mass, nine-tenths of which is made up, either of concretions or amorphous masses with vertical joints, (*a*, *a*, *a*,) whilst various small, acutely angular fragments, of gritty impure limestone with shells, (such as at *b*,) of highly curved layers of shelly sandstone (*c*), and semicircular bands of indurated shale (*e*), are twisted up in directions varying from vertical to horizontal, and lost in the great mass of trap. In one spot, a coral (*d*) is seen to be completely separated from the broken mass of shelly limestone (*b*), and included in the trappean paste.

Besides their fragmentary and dislocated condition, these detached portions of sedimentary strata are all more or less in altered conditions, being more compact and of greater specific gravity than when found in natural beds divested of their trap associates. This appears, therefore, to be one of those cases which is absolutely inexplicable upon the supposition of contemporaneous origin, since these shelly strata must have been originally deposited in regular successive layers, before they were subjected to the action which has reduced them to their present shattered condition; but if we simply view this trap as the portion of an extensive dyke of igneous matter, ranging from north to south, which in some parts has been intruded in a band between and nearly parallel to the beds, and in others has burst through and fractured them, enveloping small fragments of the strata in the mass of molten matter, we account naturally and simply for

all the phenomena. The case near Long's Quarry is equally subversive of the notion of contemporaneous deposit, as may be seen in the irregular dome of trap which has been recently exposed near the banks of the Avon.

If, however, we quit the pigmy dykes of Charfield Green, which are necessarily obscure in parts of their course, owing to the flat surface of the ground which they traverse, and examine any of the chief trappean rocks north or south of the Avon, near Damory Mill, we meet with the most unanswerable evidence of their intrusive character. If, for example, we inspect the mass extending from Avening Green to Crockley Wood, we see that it is not parallel to the strata for twenty yards together; for although not exceeding the width of 100 paces at Avening Green, where it is an irregular boss with altered rocks upon its sides, before reaching Crockley's it diminishes to a few yards, and passing by that farm house with a broken and irregular outline, it suddenly bulges out into a great mass, not less than a quarter of a mile in width, and occupying Crockley's Wood, throws off, in opposite directions, the strata in contact with its flanks. Wherever this rock does not rise to the surface, its course is well known to the farmer by the dry and absorbent nature of the soil above it, which is strongly contrasted with the heavy clays of the Caradoc Sandstone, through which the trap has forced its devious course. At Horsley Mill, where it appears to have burst out from north to south, the trap is composed of great globular concretions, partially enveloped by broken pellicles of sandstone, limestone and shale, all more or less altered and occasionally containing fossils. On tracing this trap to the edge of the Caradoc Sandstone, east of Woodford Green, the latter appears fractured and distorted in every imaginable direction, points of the former protruding here and there through the broken and indurated strata, which are thrown off towards Woodford Hill. All the evidences in Michaelwood Chace are equally decisive of the intrusive character of the trap, but especially at the extensive quarries opposite Damory Mill, where a short and very uneven ridge of the rock rises up through the sandstone, and produces the picturesque and rocky outline in the gorge of the Avon. In their central portion, where deeply cut into, these fine quarries present nothing but reddish and greenish trap, usually arranged in large concretions[1] which exfoliate concentrically, and in them we find passages from varieties of tuf and amygdaloid, to beautifully compact, crystalline greenstone. Not a trace of sedimentary deposits or of fragments containing fossils, is detectable in the central part of this mass of volcanic matter, but as we ascend to the surface and flanks of the quarries, coatings of serpentine appear on the joints of the rock, and finally beds of purple and green shale, with bands of sandstone full of fossils (including the small ornamented trilobite *Trinucleus*), are tilted off from the sides of the protruding mass, dipping in different directions, some of them to the south, others particularly on the left bank of the river to the south-west, indicating a force acting

[1] A single concretion which I observed in the Damory quarries measured twelve feet by six.

from the northern side in Michaelwood Chace, where the greatest volcanic vent seems to have been opened.

We may further remark that it is scarcely possible to cast the eye over the annexed map without supposing, that the forcible intrusion of the trap must have had a powerful influence, in throwing the sedimentary deposits of this tract into the broken, contorted and complicated forms in which we now find them. Looking at the position of the Silurian rocks of Tortworth, we perceive, that they constitute the termination of a line of elevation proceeding from N.N.W. to S.S.E., and which originating in the valley of Woolhope, passes by May Hill, Aram near Newnham, the Milkmaid rock and Purton passage; from whence they are prolonged through Michaelwood Chace into the remarkable prongs which embrace the Old Red and Carboniferous deposits. This bifurcation of the Silurian rocks, has precisely the form which sedimentary deposits would assume, from igneous matter having been emitted along such lines, since besides the chief masses of trap which protrude in irregular bosses, at many points within the area of little more than a square mile, the rock strikes out thence as from a centre, and takes a forked direction. One mass points S.S.E. through Priestly Wood, the other passing to the W.S.W. disappears beneath the surface at Avening Green, but finally reappears at intervals at Charfield Green, in small irregular dykes. The highly inclined, truncated and broken edges of the Silurian rocks along the external edges of the area which they occupy; and the domes and arches in which they appear near Falfield and Whitfield, all harmonize with the supposition, that the volcanic matter which has reached the surface in the environs of Michaelwood Chace, has not been able to rise from beneath its rocky covering on the south, but in struggling to find a vent has there given rise to the curvatures and breaks of the overlying accumulations[1].

It was formerly my belief, that this elevatory influence did not extend beyond Milbury Heath; but having recently visited that part of the district, accompanied by Mr. S. Stutchbury, my attention was called by him to a remarkable tongue of Old Red Sandstone, which extending beyond the limits I had assigned to my map, runs from E.N.E. to W.S.W., through the carboniferous limestone of Old Down.

This narrow ridge is in truth a distinct prolongation of the axis of Milbury Heath. On one side the beds dip to the S.S.E. beneath the limestone of the Ridgeway and Alveston, whilst on the other the Red Sandstone presents a mural escarpment, against which the ends of the slightly inclined strata of the limestone are abruptly truncated; thus exhibiting a line of powerful fault on the north-western side of the anticlinal. (Pl. 36. f. 22.) This limestone of Alveston Down is in part of oolitic structure, and contains several well-known fossils. Where it is in contact with the Old Red Sandstone, the whole mass for a width of twenty or thirty paces has been powerfully affected, and

[1] Charfield Green may have been elevated en masse, as the country rises on approaching it from east to west.

is full of vertical joints and fissures. That the direction of these joints (many of which have slickenside surfaces), has been caused by the same operation which produced the great anticlinal, there can be little doubt; for the dominant planes are parallel to the strike of the Old Red Sandstone. This ridge finally subsides at its west-south-western end, by sinking on two sides beneath the limestone.

In conclusion it may be remarked, that vast masses of the overlying formations of New Red Sandstone, Lias, and Inferior Oolite, must have been removed by the powerful denudations which doubtless, both accompanied and followed the intrusion of the trap rocks and the dislocations of the strata; for as soon as we quit the small arena of agitation around Tortworth, and recede from the proximity of rocks of igneous origin, the overlying formations resume their regular positions. (See Map.) We may further conclude, that volcanic rocks, either rising to the surface or struggling to emerge, threw up the band of elevated Silurian rocks which has been traced in an anticlinal form from the Valley of Woolhope to Alveston Down, near Bristol.

# CHAPTER XXXV.

## ON THE DUDLEY OR SOUTH STAFFORDSHIRE AND WORCESTERSHIRE COAL-FIELD.

*Introduction.—General arrangement of the Coal-field.—Account of the Formations in descending order.—Lower New Red Sandstone.—Volcanic Grit or Tufaceous Conglomerate.—Coal Measures, including the Upper and* 10 *yard Coal, and the Lower or Ironstone Measures.—Shaft Sections.* (Pl. 37. figs. 1 to 5.)

ALTHOUGH replete with scientific interest from the variety of its rocks and the dislocations of the strata, this highly productive coal-field has received little attention from geologists; a circumstance the more remarkable, when we consider that it supplies Birmingham, one of the greatest seats of manufacturing industry in Great Britain, with coal and iron. The apparent neglect may, however, be partly explained, by the most valuable portion of the tract having been so well described by Mr. Keir[1], that, notwithstanding the long period since its publication[2], his sketch is still, in many respects, considered a good general view of the coal-bearing strata. The notices concerning the tract which have since appeared are, indeed, little beyond slight additions to the memoir of Mr. Keir, for none of them have attempted to offer more extended views, by explaining the relations of the rocks associated with the coal. In short, no endeavour has been made to point out the position and age of the red sandstone which surrounds the coal-field, nor to indicate the succession of the older strata beneath it.

The following sketch, I trust, will show the true nature of these formations, though it is far from being a complete history of the coal-field. On the contrary, I venture to propose it as a foundation only, on which, if it be sound, future geologists may build,

[1] See Shaw's History of Staffordshire, General History, p. 116.

[2] We must exempt from this observation "A sketch of the country round Birmingham," by Dr. Thomson, (Annals of Philosophy, vol. viii. p. 164.) in which the author makes some good original observations, and draws accurate lithological distinctions, though he does not enter into the question concerning the older rocks, and, in our opinion, misconceives the relations of the red sandstone to the coal-field. This sketch of Dr. Thomson is quoted in the Outlines of the Geology of England and Wales, p. 411. Several interesting points are also touched upon by the Rev. J. Yates in a memoir in the Transactions of the Geological Society. These will be alluded to in the sequel.

while they enrich the stock of knowledge with details concerning a region so interesting to men of science, from the complication and variety of its natural phenomena.

### *General relations of the Coal-field.*

The surface of this field is much covered by gravel, clay, and boulders. A few of the latter, particularly in the Wolverhampton tract, have been derived from distant places in the north; but the chief masses of finer detritus have resulted from the abrasion or breaking up of the Lower New Red Sandstone, mixed up with fragments of trap, particularly where the coal strata have been forced up through it. The debris of red sandstone constitutes, occasionally, mounds of great thickness, which might at first sight be mistaken for undisturbed portions of the formation. These, as well as the other loose superficial materials, will be considered in subsequent chapters.

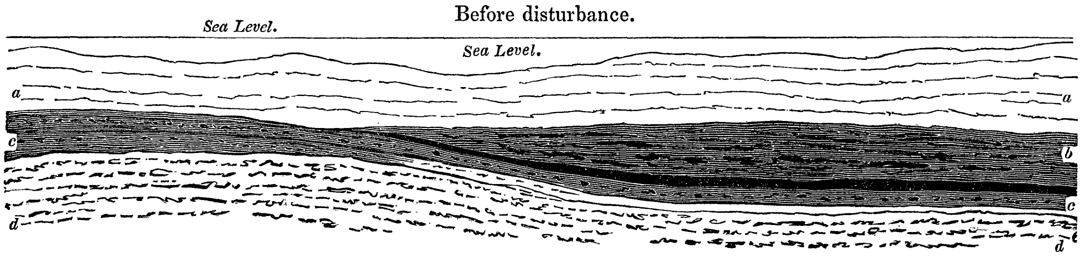
The youngest formation, *in situ*, is the Lower New Red Sandstone, by which, as already shown, the coal-field is surrounded (p. 54 *et seq.*), and which passes down conformably into the coal-bearing strata. Notwithstanding this field contains the thickest seams of coal in England, its associated strata are of very small dimensions compared with the equivalent series in other parts of the kingdom. The millstone grit is scarcely represented; and the mountain limestone, the usual base of the system, as well as the Old Red Sandstone, are entirely absent. "The absence of these formations," as Mr. Conybeare has well observed, "and the immediate contiguity of the coal measures and a transition rock (the Dudley limestone), constitute a remarkable and important character in this coal-field[1]."

The real substrata of the coal deposits consist of various members of the Silurian System. These ancient rocks, however, instead of appearing in the regular order in which they have been described in other parts, rise up irregularly, like islands, through the coal measures near Dudley and Sedgeley, and form the eastern boundary of the field near Wallsall. Such relations will be understood by reference to the two general sections across the tract. (Pl. 37. figs. 1 and 2.) To convey, moreover, to the reader some conception of the original condition of these deposits, both before and after their elevation, I annex two wood-cuts.

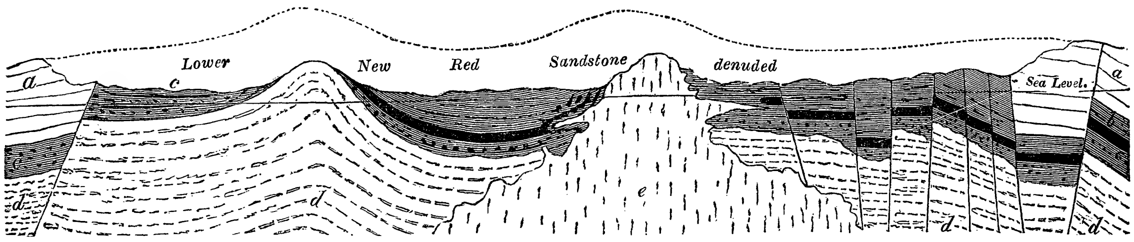
The first is an ideal representation of a carboniferous group of strata, one portion of which (*b*) comprises overlying thick coal seams, the other (*c*) lower coal measures which spread out beyond the thick coal; the whole resting upon Silurian rocks (*d*) and covered by the Lower New Red Sandstone (*a*). The second represents a generalized outline of the condition of such strata after the sedimentary deposits were pierced and dislocated by volcanic rocks (*e*) and thrown into their actual positions.

[1] Outlines of the Geology of England and Wales, p. 416.

Before disturbance. 99.




After disturbance. 100.




*a.* Lower New Red Sandstone. *b.* Coal Measures with thick Coal. *c.* Lower Coal and Ironstone. *d.* Silurian Rocks. *e.* Trap.

It was the desire to understand the anomalous protrusion of the Silurian and trap rocks, which induced me to examine the district, and in acquiring a knowledge of their position, I have necessarily become acquainted to some extent with the overlying carboniferous strata.

That portion of the field, of which Dudley may be called the centre, and which extends northwards to Wednesbury and Bilston, and southwards to near Hales Owen, is filled with the thickest masses of mineral matter, constituting two great divisions, in the upper of which is the celebrated 10 yard coal; in the lower, seams of less thickness, alternating with beds of ironstone. (See Map[1].) To the north, the overlying or thick coal crops out, and the lower or ironstone measures rise to the surface, and occupy the district between the towns of Wolverhampton and Wallsall. Though varying much in their mineral contents, they probably range through all the carbonaceous tract, extending by Wednesfield Heath, Bloxwich, and Essington to Cannock Chace and Beverton, near Badgeley[2]. In like manner, and at the south-western end of the tract, near Stourbridge, the lower carboniferous strata again rise for a small

[1] I may here remark, that in the map the portion of the district which contains both the thick coal and the lower measures is marked by a *deeper tint of black*.

[2] I have not well examined this north-eastern tract beyond the Lanesfield and Monmore collieries. The continuation of this coal tract, extending from Cannock Chace to Beverton, lies indeed, beyond the limits of the published sheets of the Ordnance Survey; which work, as before explained, is the foundation of the accompanying map. (See Introduction.)

space from beneath the 10 yard coal, occupying a nook, in which they fold over and dip beneath the Lower New Red Sandstone. To the south, east and west, however, the whole of the carboniferous masses (i. e. both the thick and thin coal) are brought up against the Lower New Red Sandstone by enormous faults.

It was till very recently a prevalent belief, that this red sandstone entirely cut off the coal, and that the latter would never be found under the former; but this notion, (like the vulgar error concerning the magnesian limestone of the North of England, which has long been dissipated,) is now fast vanishing, and will, I trust, be entirely removed from the minds of the practical men who may favour me with a perusal of these pages[1].

After this preamble we may proceed to the consideration of the Lower New Red Sandstone and Coal Measures, including certain tufaceous conglomerates or volcanic grits which alternate with both these deposits, and in the next chapter complete the geological history of the tract by describing the Silurian rocks on which the coal-field rests, the trap rocks by which it is penetrated and altered, and the dislocations by which it is affected, concluding with some general observations on the extension of coal beneath the New Red Sandstone.

### *Lower New Red Sandstone.*

Exclusively of loose detritus, the Lower New Red Sandstone, as already shown, is the youngest formation in the vicinity of the coal-field, around which it forms a continuous and widely spread mass. (See Map.) The deposit has been previously stated to be of great thickness in this district, as proved both by natural sections around the edges of the coal-field, and by the sinkings of the Earl of Dartmouth. (See p. 58.)

In mineral characters the formation varies considerably in different localities. We have already described, p. 56, a yellowish soft sandstone at the southern end of the field (Hodge Hill, &c.) which very much resembles the "Rohte todte liegende" of the county of Durham. This rock re-appears in open sections on the western flank of the field near Himley, Holbech, Swindon, &c. At Holbech it is overlaid by deep red, loamy, finely laminated sandstone, with layers of greenish flags dipping 35° to the north-east. At Swindon the laminæ of the soft yellowish sandstone are occasionally marked by very thin carbonaceous partings. The great mass, however, of the Lower New Red Sandstone surrounding the field, differs from the rock of the same age in the north of England, being a deep, dull red, finely laminated sandstone, calcareous in parts, with numerous whitish grains of decomposed felspar and concretions of impure limestone.

Towards the southern and south-eastern extremities of the field, the 10 yard coal, as will be shown, passes under the red sandstone. In truth, much of the tract in that neighbourhood (Corngreaves, &c.) which is now part of the coal-field, was, when Mr. Keir wrote, deemed to be *far*

[1] See my previous communications on this subject to the Geological Society of London, which memoirs constitute the rough outline of this volume.

*beyond* its limits[1]. It has since been rendered productive by works which have pierced through superincumbent rocks, some of which must be classed with the Lower New Red Sandstone. (See subsequent sections of Corngreaves, &c.) The proofs, therefore, of the existence of coal beneath the Lower New Red Sandstone are not confined to the eastern side of the field. They may be also seen on the western side at Sedgeley, in works which are open to the day, and where thin beds of coal have been worked at a depth of a few yards, dipping rapidly beneath a ledge of the Lower New Red Sandstone: similar examples may be observed near Brand Hall, between Hales Owen and Oldbury.

The table, p. 476, explains the order in which the strata of the Lower New Red Sandstone overlie and pass down into the coal measures on the eastern side of the field, being a detail of the shaft section of the Earl of Dartmouth before alluded to, the work having been completed while these pages were passing through the press[2].

This section has thus completely established the existence of coal measures beneath the New Red Sandstone, beyond what was formerly considered the eastern barrier of the "coal field." That these measures may thin out in that quarter, and that profitable *commercial* enterprize cannot well be undertaken by pursuing operations still further to the east, is a separate consideration. In the mean time, though it would appear, that the coal in question thins out and is much dislocated, it has been equally ascertained that it thickens as the works proceed *westward*; and this we should expect; for as at the great fault at the former boundary of the field, the coal was ten yards thick, so have we every reason to conclude that the mineral will gradually expand from the distant point where Lord Dartmouth's shaft has been sunk, till its full development on the untried side of the fault as represented in the diagram, Pl. 37. f. 1. This is the first shaft which has been sunk through a *thick* portion of Red Sandstone, and being nearly *one mile distant* from the fault by which the coal was supposed to be *cut off*, the value of the discovery is great in confirming the views of geologists[3]. On the western side of the field, speculative sinkings have also been commenced in the red formation, and when I quitted the district one had proceeded to a depth of about 100 yards. This

[1] To show how much the limits of the field have been recently extended, its greatest breadth near Dudley was stated to be four miles when the Outlines of Geology of England and Wales were published, 1822, p. 407. The width over which coal works are now spread is about nine miles from east to west, without reckoning the coals which have been proved *beneath* the red sandstone.

[2] The rocks in this section are described with tolerable precision, because specimens from each stratum passed through were submitted to my inspection, and are now, through the liberality of the Earl of Dartmouth, and the zeal of his agent Mr. Dawson, deposited in the museum of the Geological Society. By a letter received, while these pages are printing, it appears that Mr. Dawson is now sinking beneath the bottom of the present works, given in the section, p. 476; having driven a head-way to the east, where he had been led to suppose that the Red Sandstone is, by a great oblique fault, brought down to be a few yards only above the bed of coal in work.

[3] Other trials on the east side of the field have been recently made, and in one of them near Oldbury the coal has just been won. December 1, 1837. (See further observations on these dislocations in the ensuing chapter).

subject, being connected with the lines of dislocation along the frontier of the coal field, will be resumed towards the conclusion of the next chapter. I will here only remark, that in the shaft of Lord Dartmouth and the other situations alluded to, the Lower New Red Sandstone has been affected by all the dislocations which have disturbed the coal measures, and that the two formations are everywhere in *conformable* position, both at high and low angles of inclination.

### *Volcanic Grit or Tufaceous Conglomerate.*

Besides the shale and sandstone common to all coal fields, this tract is distinguished by containing a peculiar grit, frequently tinged green; the "Espley rock" or "Blue rock" &c. of the colliers. It occurs in moderately thick strata in the central portion of the field between West Bromwich on the east and Kings Swinford on the west. In the southern district, however, i. e. south of the Netherton Canal, it expands to vast thicknesses, and there forms the connecting link between the coal measures and the Lower New Red Sandstone. On exposure it weathers to dingy yellow, red and green colours[1]. The round topped hills of Haydon, which are formed of it, may be taken as a centre, from whence it extends to the southern end of the Rowley Hills, and all over Gorsty Hill through the district ranging from Hales Owen by Corngreaves and Homer Hill to Cradley. This rock is briefly alluded to by the Rev. J. Yates (Geol. Trans. vol. ii. p. 253.) and called a trap tuff, but neither its relations to the productive coal measures nor to the other trap rocks have been pointed out. From the vast quantity of trappean matter in its composition, I have no hesitation in considering it a variety of volcanic grit, and as it alternates in many beds, both with the Lower New Red Sandstone and the upper strata of the coal measures, there can be little doubt that it was formed from the detritus of submarine volcanos, which *were in activity* towards the close of the accumulation of the coal measures. It, therefore, exhibits vestiges of the earliest volcanic action traceable in these parts; for in the sequel we shall show that the other trap rocks of this district (Rowley Hills, Barrow Hill, Pouk Hill, &c.) instead of having a depositary character, have all been intruded forcibly into the strata *after their* consolidation, because they dislocate and break up the coal measures together with the volcanic grits under consideration. All the shaft sections in the neighbourhood of Corngreaves pass through great thicknesses of this grit[2], which may also be studied in natural sections in the deep ravines of that picturesque and hitherto little worked portion of the coal-field which ranges from Gorsty

[1] See the dotted tract on the map extending from Hales Owen to Netherton and the south end of the Rowley Hills.

[2] See section, No. 3. p. 477, of the principal shaft of the Corngreaves works, obligingly given me by Mr. Best, director of the British Iron Establishment. In this case I examined the specimens brought up from the original sinkings.

Hill and Corngreaves to Hales Owen. At the Rag Mill, on the banks of the little stream near Corngreaves, a vertical cliff of 30 to 40 feet exposes in descending order the following strata.

1. Coarse conglomerate of flattish and slightly rounded pebbles of quartz, compact felspar, and various trap rocks, varying in size from a child's head to a bean, and imbedded in a greenish grey matrix of trappean detritus with fragments of green earth.

2. Mottled, dark red and dingy yellow, marly, granular, softish grit, occasionally passing into concretions of red marl or clay.

3. Dingy green rock or volcanic grit (the blue rock of the workmen) made up principally of scoriaceous matter. It is regularly interstratified in beds varying from 8 to 12 feet, but like all depositary strata in this tract, it so wedges out, that some shaft sections pass through a much greater number of beds of it than others.

I shall return to the consideration of the origin of this deposit in the next chapter, having here merely described its composition and connection with the other stratified deposits which *overlie* the coal.

*Upper Coal Measures and* 10 *yard Coal.*—In a district so much covered with loose detritus, and in which the records of different shaft sections are full of discrepancies, depending sometimes on natural distinctions, such as the thinning out of one stratum and the setting on of another, but often upon inaccurate data, it is useless to record all the details. Such only, therefore, as I think can be depended on, and may serve to establish general views, are brought forward[1].

Owing to the great disturbances to which that part of the field which contains the "ten yard coal" has been subjected, whether by the upheaval of the Silurian or trap rocks, or by great dislocations both longitudinal and transverse of which we shall treat hereafter, the same measures are reached at very various levels in different localities. Thus, in some situations, shafts are sunk through shale and clunch with bands of sandstone, to depths exceeding 100 yards, before traces of coal are met with; while in many collieries, as near Wednesbury, all the overlying seams of coal and coal-smut which connect the coal measures with the Lower New Red Sandstone, have been removed or have thinned out, and the ten yard coal rises at once to the surface. It was this natural outcrop of the thick coal which led our ancestors to work it in open quarries. As soon as these day works were exhausted, shafts were sunk where the strata dipped beneath

[1] Since these chapters were written, an useful, small work (explaining the method of working coal mines), has been published, entitled the Miner's Guide, by Mr. Thomas Smith. The reader will find that the details of every shaft section therein, differ from those I have collected, thus adding strength to the argument founded on the variety of composition of the strata in different parts of the field. At Highfields near Bilston, for example, the "flying reed" is stated to be *sixty-eight* yards above the "ten yard coal," while at Deepfield, also near that place, the same coals are separated by *twenty-eight* yards only of measures. Mr. Smith also gives a section of unsuccessful boring through the Red Sandstone at Smethwick, to a depth of 187 yards.

This author does not attempt to point out the order of superposition of the fundamental rocks. He talks, for instance, of the Dudley limestone as *mountain limestone,* and describes the concretions of the Sedgely limestone as having been rounded by *attrition,* so as to form a conglomerate; and further, considering this field a basin, he states that its old limits being marked by nature, will not be found to extend beyond its present boundaries!

the surface, and the same thick coal was regained at depths, varying from one to two hundred yards. In sinking these shafts, the miner soon perceived, that the coal measures generally succeeded each other in a given order. Thus, he found in descending, that at a certain number of yards (more or less in different places) courses of smut and poor coal, including the two foot seam, were interlaminated with shale and sandstone; that passing through these strata, a bed of good coal occurred, from two to five feet thick, and again penetrating through numerous other strata, in some places containing an uncertain seam of coal (the flying reed or red)[1], he reached the same thick mass of coal which had been previously worked out at the surface. Again, in sinking to greater depths, lower coal measures with iron stone were discovered. The uppermost coal bed worthy of notice was termed the "broach coal," as being the index by which the rich field was *broached* or *tapped*. In like manner a variable coal seam which expanding and contracting (occurring at intervals only), received the name of "flying reed." Now in most of these details we have little more than the ordinary accompaniments of other coal-fields; for in previous chapters we have abundantly explained, how a stratum which is composed of sandstone in one part of a field, tapers out and passes into clunch and shale at no great distance; while coal beds deteriorating in their course, become shale, and beds of shale (often in a very short horizontal distance), graduate into coal. (See pp. 101—102.)

In consulting the sections, p. 477, the reader will find abundant proofs of these conditions. Thus the "broach coal" occurs at very various depths. In one shaft, it is separated from the great coal by a considerable thickness of measures, including the "flying reed coal," while in another the "broach" and the "great coal" lie within a few yards. These phenomena are, indeed, no longer subjects of surprise to geologists, since they are explicable by reference to the natural operations by which sand, gravel, mud and vegetable substances have been, and ever will be, accumulated, under large lakes and seas. On this point I refer my reader to the general views concerning the origin of coal-fields, p. 148.

The prevailing succession of the coal strata in the central parts of the field, where works had been long in existence, is given by Mr. Keir, and is copied from his letter into Dr. Thomson's sketch, and thence into the Geology of England and Wales, p. 409. These sections, however, referred merely to a limited tract, then known as the coal-field, rigorously bounded as it was supposed by certain faults. I therefore annex other sections of shafts more recently sunk in various parts of the field which establish the

[1] The Flying Reed, as described by Mr. Keir and Dr. Thomson, is where the two upper beds of the ten yard coal separate from the chief mass; beds of shale, ironstone, &c., setting in between them for a thickness sometimes of about twelve feet. In a section, however, at King Swinford furnished by Mr. Downing (No. 1. table, p. 477.), the Flying Reed is separated from the thick coal by upwards of forty-two yards of measures ! ! so little is a section taken from any one part of the field applicable to another. In this respect the field much resembles that of Coalbrook Dale. (see p. 101.)

succession of very different strata[1]. It is difficult at this day for any geologist to determine the precise relations of all the upper strata in every part of the coal-field which has been long worked, so much is the surface obscured, and so frequently have all records perished. It is, however, sufficient to state generally, that in most parts the upper measures consist of shale or clunch, with occasional courses of sandstone; the former being in much the greatest abundance, though the latter rises to the surface in some places, as near Wednesbury and Bilston. The Wednesbury rock is one of the highest in the series, occurring about 30 yards above the main coal, and being about 8 or 9 feet thick. That of Bilston lies immediately above the main coal, is 10 yards thick, and occurs in both thick and thin beds, the former variety being used for building purposes, the latter being a grit for whet and grindstones, &c. None of these sandstones have any considerable horizontal extension.

Without further explanation of the nature of the superjacent rocks, I at once refer the reader to the shaft sections, p. 477, by comparing which he will perceive that great variations in the lithological characters of the strata take place, even in very short horizontal distances. Examining, for example, the order of the beds at the Bare Moor and Corngreaves Collieries, distant from each other only half a mile, among other marked discrepances between the various seams of coal, ironstone and measures, it will be perceived, that the white sandstone rock, which immediately overlies the *thick coal,* is at one pit 35 yards thick, at the other only 4 yards. (See table, Nos. 2 and 3.)

Before we quit the consideration of the 10 yard coal-field, it should be stated, that other masses of carbonaceous sandstone and grit, which rising up at intervals, throw off on their flanks the coal measures, must be considered the inferior carboniferous strata, properly so called, of this portion of the tract.

The fine-grained, thickly bedded, light-coloured sandstone (an excellent building-stone), of which there are such splendid open quarries near Darlaston, north of Wednesbury, clearly rises from beneath the 10 yard coal and immediately overlies the new mine coal (the uppermost coal met with at Darlaston), the superior measures being absent. These beds, about 70 feet thick, are very rich in fossil plants, the forms of which, as marked by black carbonaceous matter, are beautifully contrasted with the light-coloured sandstone in which they are imbedded[2]. The lowest of these sandstones is probably the yellowish gritty rock of Gornals, between Dudley and Sedgley, which rises as a dome

[1] These shaft sections are selected from a multitude of documents, because they describe the structure of those parts of the district which have been most recently opened out, and therefore most clearly indicate the differences between the strata now developed and those formerly known.

[2] I made no collection of the plants of this coal-field, and am therefore unprepared to give a list. Many of them, however, from both the sandstone and the shale, are already published in Lindley and Hutton's Fossil Flora, and I have no doubt that in so rich a fossil herbarium some new species will be detected. A few splendid examples, from the sandstone near Tipton, may be seen in the vestibules of the British Museum. The cabinets of the Geological Society also contain specimens.

and is extensively quarried, exhibiting thick bedded strata, largely used for building and containing impressions of stems of plants and occasional thin partings of coal smut.

*Lower Coal and Ironstone Measures.*

It has been stated, that the lower coal and ironstone measures crop out from under the 10 yard coal and extend into the great Wolverhampton field. In their spread to the north, however, these lower strata assume very different lithological and mineral characters, from those where they underlie the thick coal at Dudley, Corngreaves, and in the portion of the field south of Bilston and Wednesbury. In most of the works, which have hitherto been established, in the region of the 10 yard coal (near Dudley or south of it), three courses only of workable iron ore have been ascertained; whilst in the Wolverhampton district six valuable bands are wrought[1]. Some persons may think that this apparent dissimilarity between the productions of the northern and southern fields does not really exist, but is merely due to the want of sufficiently deep works. This opinion ought to have some weight in arguing upon the unproved beds which may exist beneath the strata covering the coal near Hales Owen. It cannot, however, apply to the great central body of the coal-field; for there the very lowest measures appear repeatedly at the surface, in consequence of the protrusion of the Silurian and trap rocks, and hence the practical miner has long been acquainted with the very bottom of the field. Such outcrops occur around Netherton Hill—along the edges of the hills of Dudley and Sedgley, particularly on the east side of the road from Dudley to Sedgley—at Wednesbury; and in none of these is there an indication of the rich ironstone measures which occur in the Wolverhampton field. Hence the speculators in the southern or 10 yard coal tract have always confined their sinkings to the beds with which they were acquainted, and which seemed peculiar to their district[2].

At Stourbridge, where the lower measures occupy a nook, flanked on three sides by the Lower New Red Sandstone, and on the fourth rise from beneath the 10 yard coal; though containing beds of ironstone, they are chiefly worked on account of the saponaceous quality of the shale or fire clay which is here so largely used for fire bricks. Three workable seams of coal have been wrought,

[1] By a band of iron ore, I mean one of those groups of concretions and imperfect beds in which two or more courses of the ore are often separated from each other by shale or clunch. Thus, though we talk of six bands of iron ore near Wolverhampton, the reader will perceive, that these constitute in reality 14 courses. (See Table, p. 479.)

[2] The general reader may be informed, that land in the productive ironstone tract of Wolverhampton, where the lower coal *only* exists, is much more valuable than in the southern district, where both the thick and lower coals are present. This anomalous assertion is reconciled by the fact, that the southern tract is so much less rich in iron ore than the northern. It is seldom, indeed, that the mere existence of coal of any thickness and of the very finest quality will of itself repay the speculators, and hence it is usual to transport the iron ore from the Wolverhampton field to the pit mouths of the thick coal, south of Dudley, and there to smelt it.

each averaging about 6 feet in thickness, and about 15 feet beneath them is the 4 foot bed of celebrated fire clay.

A good natural outcrop of the coal measures is seen on the eastern side of the Hayes. This has been already alluded to, in treating of the Lower New Red Sandstone, and will be again adverted to in describing the Silurian rocks which there cut out the coal. But the best of all the natural outcrops of the lower coal beds which fell under my notice occurs near Ettingshall. The strata there rise at angles of 30° and 35° from under the thick coal of Bilston, and appear successively at the surface, on the side of the south-eastern end of the Silurian rocks of Hurst Hill, particularly near the Coppice Meeting-house, as represented Pl. 37. f. 4.

Three seams of coal are worked, and called the *top*, *new mine*, and *bottom*, with two courses of fire clay, the lower of which lying beneath the bottom coal, as at Stourbridge, is considered the most valuable. These lower measures are overlaid by a ferruginous grit and thick-bedded sandstone (a good millstone grit) containing many impressions of plants.

Four sections, furnished me by Mr. Downing, of the lower coal measures and ironstone, are annexed (table, p. 478.), and as these are taken from shafts sunk near the northern end of the 10 yard field, they are valuable accompaniments to those furnished from its southern end by Mr. Best, p. 477. From these it will be seen, that as the field ranges to the north, the underlying measures become more impregnated with iron, and in the Bilston Meadow pit we already perceive seven courses of iron ore, of which five are of good quality.

The structure of the northern end of these coal tracts has been well ascertained in the neighbourhood of Wolverhampton, and also between that place and Wallsall, where the ironstone measures approaching the surface have been very largely worked.

The first of the sections, p. 479, is that of the shafts at the Willington Colliery, near Wolverhampton[1], and may serve as a good type of the most valuable ironstone measures known in that district.

The other sections on the same page relate to various parts of the northern field near its eastern limits. See table, p. 480.

By comparing the section of the strata near Wolverhampton, p. 479, with those given (p. 478.) in the neighbourhood of Bilston, we see how materially the strata of the same age have changed their characters and dimensions in about two miles. Near Bilston, the heathen coal is separated from the new mine coal by $37\frac{1}{2}$ yards of intervening measures. At Willington, near Wolverhampton, these seams are 51 yards apart, some of the intermediate beds having greatly expanded, while others have dwindled away; the new mine coal, for example, which is about 4 yards thick near Bilston, having become little more than 2 at the Willington Colliery.

In like manner, although the last-mentioned section affords an average sample of the coal strata near Wolverhampton, it does not apply to the area north or west of that place. Thus, the section through the whole of the coal measures at the Rough Hills, north of Rushall and Daw End, differs very materially, while at the Birch Hill Col-

[1] Supplied by Mr. W. Barker.

lieries, the detail of the beds annexed is in many respects peculiar and unknown in other parts of the field. (See sections, p. 480.)

These sections exhibit many repetitions of strata, which slightly differing from each other in mineral ingredients, and succeeding each other in finely laminated beds of different colour, must have occupied a very lengthened period in their accumulation. In pointing out the discrepancies in mineral characters between strata of the same age in different parts of the field, it is obvious, as before stated, that such phenomena are strictly analogous to what we should suppose to have resulted from the circumstances under which such strata were accumulated. (See pp. 149 *et seq.*)

This northern part of the coal-field is interesting to geologists, not only as abounding in well preserved impressions of plants (for these are common to all coal-fields), but in containing a considerable number of animal remains which are of rarer occurrence in the southern tract[1]. These consist of several species of *Uniones* and *fishes,* some of which appear in the ironstone concretions, but the greater part are found in the beds of black "*bat,*" a dull, compact, bituminous shale, which sounds under the hammer like wood, and splits into flat and thinly laminated fragments. The *Uniones* occur in great quantities in some of the old works in the western slopes of the Birch Hills, near Bentley Hills, and also in the Lanesfield collieries. They consist of several species which have been examined by Mr. J. Sowerby, some of which are new and will be published in the Mineral Conchology.

At Lanesfield, these shells are associated with the remains of several genera and species of fishes, which, according to M. Agassiz, are

*Megalichthys Hibberti,* Agassiz.
*Megalichthys Sauroides,* Agassiz.
*Diplodus gibbus,* Agassiz.
*Coprolites of fishes* and *scales,* &c.

These organic remains are of great interest, in establishing a geological identity between the coal measures of the Dudley district and those of distant parts of Great Britain. The same *species* of fishes, associated with scales, teeth, coprolites, &c., are here found commingled in a finely levigated, hard, black shale[2], precisely similar (I speak in both cases from personal comparison) to that in which they were first discovered by Dr. Hibbert at Burdie House near Edinburgh, and I have no doubt that an assiduous fossil collector in the Staffordshire field would discover many more of the species which occur in the rich emporium of the Scotch coal measures. That these remains have also been deposited in the adjacent coal-fields of north Stafford[3] (Newcastle

[1] I have just been informed, and therefore too late to become acquainted with the species, that Mr. Blackwell of Dudley possesses some fine specimens of fishes from the Dudley coal-field.

[2] The bat of Staffordshire.

[3] I have indeed myself received specimens of this coal tract from Mr. Garner, among which, besides the two common species of *Megalichthys,* Professor Agassiz recognised *Holoptychus,* another of the genera found at Burdie House, but of a new species, to which I hope he may assign the name of *H. Garneri.*

under Lyne, &c.) has been already proved by the discovery of Sir Philip Egerton, Bart., who has found at Silver Hill near Madeley (see map) several species, including those observed by myself in this district, associated with the same *Uniones* as in the Wolverhampton field. Again, several species of these *Uniones* are equally abundant in the coal-field of Coal Brook Dale, where the discoveries of Mr. Prestwich prove that they are also found in ironstone measures associated with the same fishes[1].

The marked differences in the mineral character of the measures of the north or Wolverhampton tract, as compared with those of the Dudley district, are not confined to the beds of coal and ironstone; for while in parts of the Dudley field, large masses of sandstone form the base of the carboniferous series, such rocks are wholly wanting in the northern tract, the strata of shale and ironstone being at once incumbent upon Silurian rocks.

[1] I have little doubt that, when well examined, all the coal-fields of England will be found to contain the characteristic species of the Scottish and other coal-fields already published by Agassiz. Mr. Bowman of Gresford called my attention some time ago to the fact of the prevalence of *Megalichthys* and other fishes in the Denbighshire coal-field.

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In referring my readers to the instructive shaft sections in the following pages, I cannot avoid noticing the obligations I owe to several gentlemen connected with this coal-field. To the names of Mr. Downing, Mr. Best, Mr. J. Barker, and Mr. Dawson already mentioned, I must add those of Mr. W. Mathews of Green Hill, Mr. Bennett of Dudley, and Lieutenant Eaton, R.N., to all of whom I am indebted for much obliging assistance.

## *Section through the Lower New Red Sandstone to the Coal Measures at Christchurch.*

| No. | Description | yds. | ft. | in. |
|---|---|---|---|---|
| Loose materials. | Soil, loam, &c. | 9 | 0 | 0 |
| | Reddish clay | 1 | 2 | 0 |
| | Sand and gravel | 10 | 0 | 0 |
| | Red sand (incoherent) | 4 | 0 | 0 |
| 1. | Reddish and green argillaceous *marl*, tending to small concretionary structure | 3 | 0 | 0 |
| 2. | Dingy red and brown, hard calcareous sandstone, with small concretions and blotches of clay, sometimes of greenish colour | 2 | 2 | 6 |
| 3. | (Grey rock parting.) Hard calcareous grit, composed of pinkish and grey fragments of quartz and other rocks, in a calcareo-siliceous cement | 0 | 2 | 0 |
| 4. | Deep red argillaceous marl with small spots of green (red clunch of miners) | 2 | 2 | 0 |
| 5. | Mottled reddish brown marl, arranged in small concretions, much more calcareous than the overlying strata (light brown ground) | 2 | 9 | 0 |
| 6. | Cornstone, viz. dark purplish brown concretions of very impure, compact, argillaceous and ferruginous limestone | 0 | 0 | 9 |
| 7. | Green and red marl (effervesces slightly) | 0 | 1 | 6 |
| 8. | Slightly calcareous grit, mottled dingy red and green, with some whitish grains of felspar | 0 | 1 | 3 |
| 9. | Deep ruddle red argillaceous marl, in parts slightly calcareous | 15 | 2 | 0 |
| 10. | Mottled red and green indurated concretionary marl, approaching to cornstone | 1 | 1 | 0 |
| 11. | Brownish red and green, mottled, argillaceous marl | 2 | 2 | 3 |
| 12. | Mottled ground, as above, very slightly calcareous (rock binds of miners) | 5 | 2 | 0 |
| 13. | Slightly pinkish grey grit (identical with No. 3.) | 0 | 0 | 1½ |
| 14. | Mottled red and green sandy marlstone | 0 | 2 | 4½ |
| 15. | Fine grained red, hard, calcareous sandstone, with parting | 0 | 1 | 1½ |
| 16. | Deep red argillaceous marl, with occasional small green spots | 3 | 0 | 7½ |
| 17., 18. | Ditto. Ditto. } separated by stone partings | 1 | 1 | 3 |
| 18 *bis*. | Hard light coloured calc-grit, similar to Nos. 3 and 13. | 0 | 2 | 9 |
| 19. | Whitish and mottled green marl (highly calcareous in the partings) | 0 | 2 | 3 |
| 20. | Deep red marl, as above | 4 | 1 | 6 |
| 21. | Mottled brownish marl, small concretionary, calcareous in parts, (fire clay of miners) | 0 | 0 | 6 |
| 22. | Ruddle red marl, as above | 7 | 2 | 6 |
| 23. | Mottled layer, like No. 21. | 0 | 0 | 6 |
| 24. | Deep red and green marl | 7 | 2 | 6 |
| 25. | Dark reddish brown argillaceous marl, almost shale | 3 | 0 | 0 |
| 26. | Mottled red and green sandy marl, passing into marlstone | 5 | 0 | 0 |
| 27. | Red marl | 2 | 0 | 0 |
| 28. | Dull red, mottled argillaceous sandstone | 3 | 0 | 0 |
| 29. | Dull red, argillaceous, slightly micaceous sandstone (rock binds of miners) | 3 | 1 | 6 |
| 30. | Ochreous shale, reddish surfaces, (yellow fire clay of miners) | 0 | 2 | 0 |
| 31. | Mottled, dingy purple, calcareous sandstone, with a few small deep red blotches of marlstone highly calcareous (This rock much resembles the "grindstone" of Stanley and Higley on the Severn, see p. 60.) | 1 | 1 | 0 |
| 32. | Deep purple argillaceous marl | 0 | 1 | 6 |
| 33. | Light red, fine-grained calcareous grit, almost a sandstone, joints lined with small crystals of calc spar, partings of white grit, and basis of decomposed felspar | 6 | 3 | 0 |
| 34. | Deep purple red and green mottled marl | 2 | 0 | 0 |
| 35. | Very finely laminated red and white highly calcareous sandstone, with much ferruginous matter (*not less than* 100 *alternations in the* 3 *inches*). | 0 | 0 | 3 |
| 36. | Dull reddish brown shale, argillaceous marl | 0 | 2 | 9 |
| 37. | Dingy purple calcareous grit | 0 | 2 | 0 |
| 38. | Ditto, with greenish white marl at base | 4 | 0 | 0 |
| 39. | Dingy red shale, conchoidal fracture | 4 | 2 | 9 |
| 40. | Light greenish marl with deep red spots | 3 | 1 | 6 |
| 41. | Dingy red argillaceous grit, very slightly calcareous | 0 | 2 | 0 |
| 42. | Deep red marl | 0 | 2 | 0 |
| 43. | Mottled red and white grit, with decomposed felspar | 1 | 0 | 0 |
| 44. | Deep red slightly micaceous argillaceous sandstone | 0 | 2 | 0 |
| 45. | Highly micaceous dark red sandstone, very slightly calcareous | 0 | 1 | 6 |
| 46. | Dingy red gritty sandstone, with whitish grains of decomposed felspar, very slightly calcareous | 21 | 0 | 0 |
| 47. | Fine grained streaked ditto, with very minute spangles of mica | 2 | 2 | 0 |
| 48. | Mottled dark and light red concretionary marlstone, in parts micaceous | 0 | 1 | 6 |
| 49. | Sandstone, red and greenish, very slightly calcareous and micaceous | 7 | 1 | 0 |
| 50. | Lightish grey sandstone, streaked with purple laminæ, and is slightly calcareous | 2 | 1 | 6 |
| 51. | Dingy red sandstone, with mixed whitish grains of decomposed felspar | 4 | 0 | 0 |
| 52. | Purplish and greyish laminated sandstone | 2 | 0 | 0 |
| 53. | Dingy red sandstone resembling No. 50. | 10 | 0 | 0 |
| 54. | Hard dark purplish grit, slightly calcareous and micaceous | 0 | 1 | 6 |
| 55. | Lightish coloured argillaceous grit, with base of white felspar | 1 | 0 | 0 |
| 56. | Hard micaceous marlstone of deep red and spotted green colours and small concretionary structure. | 0 | 1 | 6 |
| 57. | Dingy red and greenish grey argillaceous sandstone, with casts of plants, crystals of heavy spar and sulphuret of iron in bunches | 3 | 0 | 0 |
| 58. | Pinkish, light grey, hard gritty sandstone, with grains of white decomposed felspar, slightly calcareous. | 24 | 1 | 0 |
| 59. | Hard dark red rock and parting; purple ditto, with greenish white spots | 2 | 4 | 0 |
| 60. | Maroon coloured shale (binds), with whitish partings and a conglomerate at the base | 4 | 1 | 0 |
| 61. | Dark brownish purple and yellowish mottled shale (fire clay) | 9 | 0 | 0 |
| 62. | Lilac coloured sandstone, separated by purple binds | 4 | 0 | 0 |
| 63., 64. | Dark red conglomerate with fragments of coal, grit, and *stems of coal plants*, pebbles of older rocks, quartz, &c., cement spotted light green, &c., with Grey shale in separating bands | 5 | 0 | 0 |
| 65. | Greenish shale bands | 1 | 0 | 0 |
| 66. | Light grey rock } Gritty sandstone | 1 | 0 | 0 |
| 67. | Dark purple rock } Gritty sandstone | 1 | 1 | 0 |
| 68. | Greenish coloured binds with grey parting | 1 | 2 | 0 |
| 69. | Dark purple binds with red spots | 1 | 1 | 6 |
| 70. | Brown binds | 3 | 0 | 0 |
| 71. | Mingled and mottled ground | 4 | 1 | 6 |
| 72. | Dark purple rock (sandstone) with binds | 3 | 1 | 6 |
| 73. | Light purple and grey ground, becoming a deep purple in descending (shale) | 8 | 0 | 0 |
| 74., 74*. | Mingled yellow and dark grey ground, with Green hard grit (volcanic grit?) *passage into coal measures* | 3 | 1 | 3 |
| | *Total thickness of Lower New Red Sandstone* | 269 | 1 | 0 |
| 75. (Coal measures.) | Grey clunch and streak of coal at 270 yards, another at 271½ yards, with "bat" at the bottom[1] | 8 | 1 | 0 |
| 76. (Coal measures.) | Grey fire clay and ironstone | 1 | 0 | 9 |
| 77. | Light greenish grey and red grit, the *Espley rock* of the miners, a sort of volcanic grit, composed of minute pebbles of quartz and trap in a greenish ground, apparently made up of volcanic detritus. Grey binds as way-boards, with seams of smut | 7 | 0 | 0 |
| 78. | Dark grey clunch and bat | 1 | 1 | 6 |
| 79. | Dark coloured fire clay, lighter towards the bottom | 2 | 2 | 6 |
| 80. | *Coal* | 0 | 0 | 6 |
| 81. | Grey fire clay | 0 | 2 | 0 |
| 82. | *Coal*, supposed to represent the "*Broach*" coal | 0 | 2 | 6 |
| 83. | Grey fire clay rock | 2 | 0 | 0 |
| 84. | *Coal*, supposed to *represent* the "10 yard coal," (varies from 8 to 12 feet) | 3 | 0 | 0 |
| 85. | Bat, GUBBING IRONSTONE, and table bat | 2 | 0 | 0 |
| 86. | Grey clunch and "LAMBSTONE," an ironstone | 3 | 2 | 0 |
| 87. | *Coal*, supposed to be the Heathen coal | 0 | 2 | 0 |
| 88. | WHITE IRONSTONE ground | 1 | 1 | 0 |
| 89. | Grey fire clay and ironstone | 1 | 1 | 0 |
| 90. | Dark grey clunch, with beds and FLATTENED CONCRETIONS OF IRONSTONE | 4 | 2 | 0 |
| | Total | 309 | 0 | 0 |

[1] "Binds" and "Clunch" are varieties of shale. "Bat" is a hard, black, bituminous shale, which sounds like a board under the hammer.

1. Kings Swinford Colliery. (Lord Ward's.)

| | yds. | ft. | in. |
|---|---|---|---|
| From the surface to the broach coal (record of the strata not preserved) | 79 | 1 | 6 |
| *Broach coal* | 1 | 1 | 0 |
| From the Broach coal to the flying reed coal | 13 | 0 | 8 |
| *Flying reed coal* | 1 | 0 | 0 |
| From the Flying reed to the Thick coal | 42 | 1 | 11 |
| *Thick coal*[1] (composed of) | 7 | 2 | 11 |

| | yds. | ft. | in. |
|---|---|---|---|
| White coal | 0 | 2 | 7 |
| Parting | 0 | 0 | 5½ |
| Tow coal, Floor and Heath coal | 1 | 1 | 4 |
| Shed and Brazils | 0 | 1 | 2 |
| Shed | 0 | 0 | 1 |
| Veins and fine coal | 1 | 0 | 6 |
| Hardstone parting | 0 | 0 | 7 |
| Stone coal | 1 | 0 | 2 |
| Parting | 0 | 0 | 4½ |
| Sawyer | 0 | 2 | 3 |
| Parting | 0 | 0 | 1 |
| Slipper | 1 | 0 | 6 |
| Benches or Kit coal | 0 | 1 | 10 |

Total 145 2 0

2. *Bare Moor Colliery.* (half a mile distant from Corngreaves.)

| | yds. | ft. | in. |
|---|---|---|---|
| Gravel and clay | 2 | 2 | 0 |
| Brown rock | 3 | 0 | 0 |
| Blue rough rock | 3 | 0 | 0 |
| Blue clunch | 2 | 0 | 0 |
| Strong white rock | 2 | 0 | 0 |
| Red marl | 12 | 0 | 0 |
| Red rock | 1 | 0 | 0 |
| Blue rock | 6 | 0 | 0 |
| Fire clay | 1 | 1 | 0 |
| Pale rock | 1 | 2 | 0 |
| Blue rough pebble rock (same as at Rag Mill) | 6 | 0 | 0 |
| Blue rock | 1 | 0 | 0 |
| Red marly ground | 3 | 0 | 0 |
| Blue pebble rock | 1 | 0 | 0 |
| Red parting | 0 | 1 | 0 |
| Blue pebble rock or blue rock | 2 | 0 | 0 |
| Grey clunch | 2 | 0 | 0 |
| *Black smut* | 0 | 0 | 6 |
| Pale clunch | 4 | 0 | 0 |
| Blue clunch | 2 | 0 | 0 |
| Blue pebble rock | 0 | 2 | 0 |
| Fire clay | 3 | 0 | 0 |
| Grey clunch, with balls of ironstone | 6 | 1 | 6 |
| 1*st. Coal* | 0 | 0 | 6 |
| Dark mixed ground | 1 | 1 | 0 |
| 2*nd. Coal* | 0 | 1 | 2 |
| Dark mixed ground | 1 | 1 | 0 |
| *Broach coal* | 0 | 1 | 8 |
| Broach stone measures | 1 | 1 | 6 |
| *Yawn coal* | 0 | 1 | 0 |
| Pins and Penny stone | 2 | 1 | 0 |
| Pale rock-binds, with balls of ironstone | 5 | 2 | 10 |
| Strong white rock (sandstone)! | 35 | 0 | 0 |
| Strong rock-binds, with stone | 11 | 0 | 0 |
| Cat heath | 3 | 9 | 0 |
| *Thick coal* | 10 | 1 | 0 |
| Bat | 0 | 2 | 8 |
| GRAIN IRON STONE | 1 | 1 | 3 |
| GUBBIN IRON STONE | 0 | 2 | 8 |
| *Heathen coal* | 1 | 0 | 6 |
| Fire clay | 1 | 1 | 0 |
| Cross stone | 0 | 1 | 0 |
| Rock and parting | 0 | 1 | 6 |
| *Bottom Heathen coal* | 0 | 2 | 6 |
| Bat | 0 | 1 | 5 |
| BALL STONE | 0 | 2 | 2 |
| WHITE IRON STONE | 0 | 1 | 2 |
| Total | 153 | 0 | 5 |

3. Corngreaves Colliery. (distance from Kings Swinford 4 miles.)

| | yds. | ft. | in. |
|---|---|---|---|
| Surface materials, &c. | 2 | 0 | 0 |
| Dry sandy ground | 2 | 2 | 0 |
| Red clay | 2 | 1 | 0 |
| White clay | 1 | 2 | 0 |
| Red sandy ground | 2 | 2 | 0 |
| Red marly ground | 4 | 1 | 0 |
| Whitish marly ground | 3 | 1 | 0 |
| Red ground | 2 | 1 | 0 |
| White soft ground | 1 | 2 | 6 |
| Red and green ground, marly, &c. | 5 | 0 | 6 |
| Red sandy ground | 5 | 0 | 0 |
| "Blue rock" and blue petrified rock of miners (volcanic grit) | 8 | 0 | 0 |
| White mild ground | 0 | 2 | 1 |
| Blue rough rock (tufaceous conglomerate) | 0 | 3 | 2 |
| Red and green ground | 5 | 0 | 0 |
| Blue bind, clod and ironstone | 3 | 2 | 0 |
| Blue soft ground | 1 | 6 | 0 |
| Red and blue ground | 4 | 0 | 0 |
| Blue hard rock, (i. e. green volcanic grit) | 4 | 0 | 0 |
| Blue mild rock | 1 | 2 | 0 |
| Whitish rock and blue soft parting. | 1 | 1 | 0 |
| Red marly ground | 11 | 2 | 0 |
| Blue rough rock (tufaceous conglomerate) | 4 | 0 | 0 |
| Marly ground | 4 | 2 | 0 |
| Blue clod | 3 | 0 | 0 |
| Blue rough rock | 3 | 0 | 0 |
| Dark clunch | 0 | 2 | 0 |
| Blue rock bind | 2 | 2 | 0 |
| Red and blue marly ground | 2 | 1 | 0 |
| Blue mild rock | 0 | 2 | 0 |
| Red and blue marly ground | 6 | 1 | 6 |
| Stray blue rock | 1 | 2 | 0 |
| Rock binds, with iron stone | 2 | 1 | 0 |
| Fire clay parting | 0 | 1 | 0 |
| Red and blue ground | 1 | 1 | 6 |
| Blue rock | 1 | 0 | 0 |
| Red and blue marly ground | 2 | 0 | 0 |
| Blue rock | 2 | 0 | 0 |
| Mixed (mottled?) ground | 2 | 1 | 0 |
| Blue rock | 2 | 1 | 0 |
| Rock binds, with rough balls of ironstone | 8 | 0 | 0 |
| Blue clunch, with ironstone | 2 | 1 | 0 |
| *Little coal* | 0 | 0 | 6 |
| Dark bat | 0 | 0 | 6 |
| Bat and fire clay | 1 | 1 | 6 |
| *Little coal* | 0 | 1 | 2 |
| Dark mixed bat | 2 | 1 | 0 |
| *Broach coal* | 0 | 1 | 9 |
| Broach stone measures | 1 | 1 | 0 |
| *Little coal* | 0 | 1 | 6 |
| PINS AND PENNY IRONSTONE | 4 | 1 | 7 |
| Rock binds | 11 | 1 | 0 |
| White rock (sandstone) | 4 | 2 | 0 |
| Brown peldan | 1 | 0 | 6 |
| White rock (sandstone) | 0 | 2 | 0 |
| ROCK BINDS, WITH IRONSTONE | 20 | 1 | 6 |
| Black bat | 0 | 2 | 0 |
| Thick coal | 9 | 1 | 11 |
| Bat | 0 | 0 | 6 |
| BLACK STONE MEASURES AND GUBBING | 1 | 2 | 0 |
| *Heathen coal* | 0 | 2 | 0 |
| Bat | 0 | 0 | 6 |
| Fire clay | 1 | 1 | 6 |
| Cross stone bats | 1 | 1 | 0 |
| Dark mixed ground and fire clay. | 2 | 0 | 0 |
| *Bottom Heathen coal* | 0 | 2 | 0 |
| Total | 202 | 0 | 1 |

N.B. The word *blue*, as used by the colliers, in mineralogical language means *green*.

[1] The following table, taken from Smith's Miner's Guide, compared with the details of the 10 yard coal above, will show the difference in various parts of the field.

10 *yard coal* (West Bromwich.)

| | yds. | ft. | in. |
|---|---|---|---|
| Rover coal | 0 | 2 | 0 |
| Slipper coal | 1 | 0 | 0 |
| White coal | 1 | 0 | 0 |
| Tow coal | 0 | 2 | 0 |
| Brazils | 1 | 0 | 0 |
| Foot coal | 0 | 2 | 6 |
| Foot coal | 0 | 2 | 6 |
| Stone coal | 1 | 1 | 0 |
| Slipper and sawyer. | 1 | 1 | 0 |
| Benches | 0 | 2 | 3 |
| | 9 | 1 | 3 |

10 *yard coal* (Highfields near Bilston.)

| | yds. | ft. | in. |
|---|---|---|---|
| White coal | 1 | 0 | 0 |
| Tow | 0 | 2 | 0 |
| Brazils | 1 | 0 | 6 |
| Parting | 0 | 0 | 2 |
| Foot coal | 0 | 2 | 6 |
| Bat | 0 | 2 | 0 |
| Slips coal | 0 | 2 | 0 |
| Stone coal | 1 | 0 | 0 |
| Patchels | 0 | 2 | 0 |
| Sawyer | 0 | 2 | 6 |
| Slipper | 1 | 0 | 4 |
| Humphreys | 0 | 2 | 6 |
| | 9 | 1 | 6 |

10 *yard coal* (Moat near Tipton.)

| | yds. | ft. | in. |
|---|---|---|---|
| Rover coal | 1 | 1 | 0 |
| Parting | 0 | 0 | 2 |
| Slipper | 0 | 2 | 0 |
| Parting | 0 | 0 | 3 |
| White coal | 1 | 0 | 3 |
| Tow coal | 1 | 0 | 0 |
| Brazils | 0 | 1 | 6 |
| Foot coal | 0 | 1 | 6 |
| Parting | 0 | 0 | 6 |
| Slips coal | 1 | 0 | 0 |
| Bat and stone | 0 | 0 | 7 |
| Stone coal | 1 | 1 | 0 |
| Slipper and sawyer. | 1 | 1 | 0 |
| Parting | 0 | 0 | 3 |
| Benches | 0 | 2 | 0 |
| | 10 | 0 | 0 |

## *Sections of the Lower Coal Measures as worked beneath the 10 yard Coal.*

### a. Highfields.

| | yds. | ft. | in. |
|---|---|---|---|
| To the bottom of the *thick coal* | 140 | 0 | 0 |
| Sundries | 9 | 0 | 0 |
| *Heathen coal* | 0 | 2 | 6 |
| Dark clunch | 3 | 1 | 0 |
| *Penny coal* | 0 | 2 | 0 |
| Strong brown blowing rock | 5 | 2 | 9 |
| COSELEY NEW MINE IRONSTONE, three measures of 2, 3 and 4 inches, lying in strong clod | 1 | 0 | 7 |
| Dark clunch | 4 | 1 | 6 |
| *Stinking coal* | 0 | 2 | 0 |
| Rock mixed with penny stone, twisted irregular ground | 10 | 4 | 2 |
| Very strong peldon | 3 | 1 | 6 |
| Dark strong rock | 7 | 1 | 0 |
| *Coal* ... 2 0 0; Parting 0 2 10; *Coal* ... 1 2 0 } *. | 4 | 1 | 10 |
| * *New mine coal.* | | | |
| Brown gritty rock | 2 | 0 | 0 |
| *Coal* | 0 | 2 | 0 |
| Dark brown fire clay, good | 2 | 1 | 4 |
| *Coal* | 0 | 2 | 0 |
| Rock | 0 | 2 | 4 |
| BALL IRONSTONE very good | 0 | 1 | 0 |
| Dark bat | 1 | 1 | 0 |
| POOR ROBIN, good | 0 | 2 | 6 |
| *Coal*, inferior | 1 | 1 | 9 |
| Rock mixed with fire clay | 3 | 0 | 0 |
| Underlying measures sunk through | 10 | 0 | 0 |
| Total | 206 | 0 | 0 |

### b. Bradley.

| | yds. | ft. | in. |
|---|---|---|---|
| To the bottom of the *thick coal* | 28 | 0 | 0 |
| Sundries | 7 | 0 | 0 |
| *Heathen coal* | 0 | 2 | 9 |
| Fire clay | 0 | 2 | 5 |
| Clunch | 2 | 0 | 5 |
| *Coal and bat* | 0 | 1 | 0 |
| Rock | 3 | 0 | 0 |
| Binds | 1 | 0 | 8 |
| Peldon | 1 | 0 | 0 |
| Rock binds | 1 | 1 | 3 |
| Little Peldon | 0 | 1 | 0 |
| Binds | 1 | 1 | 10 |
| NEW MINE IRONSTONE | 1 | 0 | 4 |
| Dark clunch | 5 | 1 | 6 |
| *Stinking coal* | 0 | 2 | 8 |
| Rock | 14 | 1 | 3 |
| *Coal* ... 1 2 7; Parting 0 2 0; *Coal* ... 2 0 0 } *... | 4 | 1 | 7 |
| * *New mine coal.* | | | |
| Fire clay | 4 | 0 | 0 |
| *Coal* | 0 | 1 | 0 |
| Fire clay | 2 | 0 | 2 |
| Fire clay balls | 1 | 0 | 0 |
| Clod | 0 | 0 | 6 |
| Black bat | 1 | 2 | 0 |
| *Coal* | 1 | 2 | 8 |
| Fire clay | 2 | 0 | 2 |
| Rock | 0 | 0 | 7 |
| IRONSTONE BALLS | 0 | 1 | 6 |
| Rock binds | 4 | 0 | 6 |
| POOR ROBIN STONE | 1 | 1 | 11 |
| Black bat | 1 | 0 | 11 |
| *Slum and coal* | 1 | 1 | 8 |
| Fire clay | 0 | 1 | 6 |
| Dark clod | 0 | 2 | 0 |
| Rock | 1 | 0 | 4 |
| Dark clunch | 0 | 1 | 0 |
| BLACK BAT AND GUBBIN | 1 | 0 | 1 |
| Fire clay | 2 | 0 | 2 |
| Slums | 1 | 2 | 0 |
| Total | 105 | 0 | 0 |

### c. Bilston Meadow.

| | yds. | ft. | in. |
|---|---|---|---|
| To the bottom of the *thick coal* | 38 | 0 | 0 |
| Sundries | 8 | 0 | 0 |
| *Heathen coal* | 0 | 1 | 3 |
| CLUNCH AND IRONSTONE | 3 | 0 | 6 |
| *Coal* | 0 | 0 | 9 |
| Black bat | 0 | 2 | 0 |
| Binds | 1 | 1 | 0 |
| Peldon and free stone | 1 | 2 | 3 |
| Ironstone measures | 0 | 2 | 0 |
| IRONSTONE | 0 | 1 | 0 |
| Mellow clunch | 2 | 1 | 3 |
| *Coal* | 0 | 1 | 2 |
| Fire clay | 0 | 2 | 6 |
| Bands | 13 | 0 | 6 |
| Peldon | 0 | 1 | 0 |
| Bands | 12 | 0 | 0 |
| Grey rock | 0 | 2 | 0 |
| *Coal* ... 1 2 3; Parting 0 1 3; *Coal* ... 1 1 4; Parting 0 0 4; *Coal* ... 0 2 0 } *... | 4 | 1 | 2 |
| * *New mine coal.* | | | |
| Fire clay | 2 | 1 | 4 |
| Black ground | 0 | 1 | 3 |
| *Coal* | 0 | 1 | 5 |
| Black ground | 1 | 0 | 4 |
| Clunch | 0 | 2 | 0 |
| IRONSTONE, very good | 1 | 0 | 0 |
| *Coal* ....... 0 1 6; Parting ... 0 0 5; *Coal*, good 1 0 0 } | 1 | 1 | 11 |
| Fire clay | 0 | 2 | 3 |
| Clunch | 0 | 1 | 9 |
| Ragged rock | 0 | 0 | 6 |
| IRONSTONE MINE, very good | 0 | 2 | 3 |
| Strong bands | 1 | 3 | 9 |
| Gritty rock | 0 | 0 | 8 |
| Fire clay | 0 | 2 | 0 |
| Dark clunch | 2 | 0 | 0 |
| Rock | 0 | 0 | 6 |
| GUBBIN IRONSTONE | 0 | 1 | 3 |
| Gritty rock | 1 | 0 | 0 |
| IRONSTONE | 0 | 0 | 6 |
| Blue clunch | 0 | 2 | 6 |
| Rock and clunch | 2 | 2 | 0 |
| Dark clunch | 1 | 1 | 0 |
| *Coal*, strong | 0 | 2 | 7 |
| Dark clunch | 0 | 2 | 6 |
| Bat and soft coal | 2 | 0 | 8 |
| Blue clay | 0 | 0 | 4 |
| FOUR MEASURE IRONSTONE | 1 | 0 | 11 |
| Total | 122 | 0 | 0 |

### d. Lane's End.

| | yds. | ft. | in. |
|---|---|---|---|
| To the bottom of *thick coal* (depth not given) | 0 | 0 | 0 |
| Blue and white clay | 1 | 2 | 3 |
| GUBBIN IRONSTONE | 0 | 2 | 9 |
| Table bat | 1 | 2 | 0 |
| Grey clunch | 5 | 1 | 9 |
| *Heathen coal* | 0 | 2 | 6 |
| Fire clay and clunch | 2 | 1 | 7 |
| Rock binds | 2 | 1 | 0 |
| Soft clunch and bat | 0 | 2 | 4 |
| *Rubble coal* | 0 | 2 | 4 |
| Rock binds | 1 | 2 | 0 |
| Strong white rock | 1 | 2 | 1 |
| Peldon | 1 | 2 | 1 |
| Rock binds | 3 | 2 | 3½ |
| NEW MINE IRONSTONE | 1 | 0 | 3 |
| Dark clunch | 3 | 0 | 0 |
| Penny stone | 2 | 0 | 0 |
| Sulphur coal | 0 | 2 | 6 |
| Fire clay clunch | 3 | 1 | 9 |
| Rock binds | 0 | 2 | 9 |
| Strong white rock | 2 | 0 | 1 |
| Grey rock | 1 | 0 | 4 |
| Strong hard rock | 5 | 1 | 6 |
| Grey rock | 3 | 2 | 8 |
| Clunch line | 0 | 0 | 9 |
| *Top coal* 1 2 8; Parting . 0 0 6; *Coal* ... 0 1 10 } * | 2 | 2 | 0 |
| * *New mine coal.* | | | |
| Batty fire clay | 1 | 2 | 9 |
| Strong grey rock | 2 | 1 | 11 |
| Rock binds | 3 | 1 | 0 |
| Dark clunch | 1 | 0 | 7 |
| *Coal* ... 1 1 11; *Coal* ... 0 2 9 } * | 2 | 2 | 4 |
| * *Fire clay coal.* | | | |
| Fire clay and clunch | 3 | 1 | 2 |
| *Phim coal* | 0 | 1 | 4 |
| Getting rock and stone | 1 | 1 | 9 |
| Strong grey clunch | 0 | 1 | 4 |
| Basses | 1 | 2 | 7 |
| POOR ROBIN IRONSTONE | 1 | 0 | 6 |
| Basses | 1 | 0 | 2 |
| WHITE IRONSTONE | 1 | 0 | 6 |
| *Coal* ... 0 1 6; Parting 0 0 4; *Coal* ... 1 2 3 } * | 2 | 1 | 1 |
| * *Bottom coal.* | | | |
| Fire clay | 1 | 2 | 4 |
| *Coal* | 1 | 0 | 4 |
| Mixed rock | 3 | 2 | 1 |
| Below the great coal | 84 | 0 | 11 |

### e. Strata sunk through in a pit at Mr. Gibbons's Level Colliery.

| | yds. | ft. | in. |
|---|---|---|---|
| Bottom of *main coal* | 0 | 0 | 0 |
| Gubbin measures and 1*st heathen coal* | 5 | 0 | 0 |
| Bat | 1 | 0 | 0 |
| 2*nd heathen coal* | 0 | 2 | 6 |
| Clunch | 7 | 0 | 0 |
| WHITE IRONSTONE MEASURES | 0 | 2 | 0 |
| Clunch | 1 | 2 | 0 |
| *Stinking coal* and fire clay | 1 | 1 | 0 |
| Strong gritty fire clay | 3 | 0 | 0 |
| Fire clay | 1 | 1 | 3 |
| Smut | 0 | 0 | 9 |
| Dark fire clay | 1 | 0 | 0 |
| Red rock and fire clay | 2 | 2 | 9 |
| Dark brown rock | 2 | 0 | 0 |
| White rock | 0 | 1 | 0 |
| Dark clunch | 0 | 2 | 6 |
| *Coal* | 0 | 1 | 6 |
| Fire clay | 2 | 1 | 0 |
| Strong dark clunch, with BALLS OF IRONSTONE | 1 | 1 | 0 |
| Dark broad binds, with shades of coal | 0 | 2 | 3 |
| *Coal* and bat | 0 | 1 | 6 |
| Fire clay | 2 | 0 | 3 |
| Strong dark clunch, with BALLS OF IRONSTONE | 2 | 0 | 5 |
| Strong white rock | 1 | 1 | 0 |
| Broad earth, with BALLS OF IRONSTONE | 1 | 1 | 3 |
| *Coal* | 0 | 1 | 0 |
| Black bat | 0 | 0 | 5 |
| Fire clay | 1 | 2 | 8 |
| *Coal* and bat | 0 | 1 | 5 |
| Fire clay mixed with stone | 1 | 1 | 4 |
| Gritty rock and fire clay | 2 | 2 | 0 |
| Blue clunch | 1 | 1 | 4 |
| Fire clay | 0 | 1 | 8 |
| *Coal* and bat | 0 | 0 | 8 |
| Rock and fire clay | 3 | 1 | 3 |
| White rock | 2 | 2 | 0 |
| Fire clay and clunch | 3 | 0 | 6 |
| White rock | 0 | 2 | 6 |
| Fire clay and clunch | 3 | 0 | 0 |
| White rock | 1 | 2 | 8 |
| Dark parting | 0 | 0 | 3 |
| White rock | 0 | 2 | 0 |
| Blue binds | 0 | 2 | 0 |
| Rock and fire clay | 3 | 1 | 5 |
| Black bat | 0 | 0 | 8 |
| Fire clay and clunch | 1 | 2 | 8 |
| Clunch and fire clay | 3 | 0 | 0 |
| Gritty rock and clunch | 2 | 0 | 0 |
| Black bat and clunch | 0 | 1 | 6 |
| White rock | 2 | 1 | 2 |
| Red clunch | 1 | 1 | 6 |
| White rock and clunch | 2 | 0 | 0 |
| Parting | 0 | 0 | 8 |
| Soft rock, with shreds of coal | 1 | 0 | 4 |
| Dark clunch | 1 | 0 | 6 |
| Soft clunch | 0 | 1 | 4 |
| Dark gritty rock | 7 | 1 | 8 |
| White spar? | 0 | 0 | 3 |
| Conglomerate | 0 | 2 | 9 |
| Light blue clunch | 1 | 0 | 0 |
| Boring in red clunch | 20 | 0 | 0 |
| Total beneath the main coal | 116 | 2 | 0 |

termination. These masses are thrown up from north to south, the strata dipping to the east and west, the latter inclination being most prevalent.

Of these masses, the principal, or that of Sedgeley, resembles in part the form of an inverted ship, the prow of which is exposed in a circling line of quarries, midway between Sedgeley and Wolverhampton, the stern towards Upper Gornals; the western side of this promontory is the most instructive, and the rocks, rising at a sharp angle, are traceable from opposite Sedgeley Park school to beyond the Catholic Chapel, a distance of nearly two miles. The higher part or round keel, separated from the western side by undulations, rises to the Beacon hill, 650 feet above the sea, whence to the eastern side the ground sinks gradually, without affording any clear exhibition of the strata. This promontory, therefore, emerges suddenly, like an island from beneath the surrounding coal measures, and thus resembles other Silurian rocks to be described.

In the numerous quarries, both along the western flank and at the northern and southern extremities, as well as near the village, the inclination of the strata varies greatly. At the northern or lower end, the arrangement of the elevated beds is beautifully symmetrical, and may be strictly compared to the bow of an inverted boat or ship, the beds plunging N.N.E., N., N.N.W. and W., at angles from 65° to 40°. In ascending to the higher grounds, the strata are much contorted, and the beds dip 25° W.S.W., whilst at the south-western extremity of the range they dip to the south-west at 25° and 10°, and then again veer round to the north-east. On the southern face, near the Catholic Chapel, the rock is inclined only 10°, and at Shaver's End is in abrupt contact with the unproductive shale and coal grits of Gornals. The arrangement on the eastern side is explained at Turl's Hill, a small offset from the main hill of Sedgeley, in which the strata dip to the west at 15°, being thrown off from the adjacent ridge of Wenlock limestone. This disposition is explained (Pl. 37. f. 4.), and in it we see how the Aymestry limestone is brought to the surface by undulations.

Of the Upper Ludlow rocks there are only thin exhibitions in the open works, which is what might be expected, since the limestone alone being the object of the quarriers, it is only extracted where there is little overlying matter to remove. Enough, however, has been cut through at various points to show the nature of the rock, particularly on the western side of the hill, where 30 to 40 feet of argillaceous thin-bedded sandstone are exposed, containing the *Leptæna lata*, the *Serpuloïdes longissima*, and other well-known fossils. From the dip of the Aymestry limestone at Turl's Hill, where it occupies the cap of a low ridge, there is little doubt that the whole of the higher part of the Beacon Hill is composed of the Ludlow rock. In these localities the beds lie tolerably level, as between Turl's Hill and Sedgeley, and probably also near the summit of the Beacon Hill. There can therefore be no doubt, that the limestone may be reached by excavations of moderate depth over a very considerable extent, an inference of some practical importance, and which renders this hill of greater value than its owners may be aware of. (See Pl. 37. f. 4.)

### *Aymestry or Sedgeley Limestone* (Limestone of the Ludlow Formation).

In passing downwards, the Upper Ludlow rock, as in Shropshire, contains small calcareous concretions. These nodular beds of impure limestone constitute the cap of the Sedgeley limestone for a thickness of 30 to 40 feet. They are underlaid by the best limestone, which varies from 15 to 21 feet in thickness, and presents regular beds of the

same dull indigo grey, argillaceous limestone as that which usually occurs in the centre of the Ludlow formation of Salop, though it is not quite so crystalline as at Aymestry. This limestone not only contains the *Lingula Lewisii* and the *Terebratula Wilsoni*, fossils which characterize it over wide spaces, but also that remarkable shell the large *Pentamerus Knightii*, which is almost peculiar to this zone. The disappearance of this fossil at many intermediate places[1] where the rock is less calcareous, and its re-appearance at so distant a point as Sedgeley, where calcareous matter is again abundant, is one of the best proofs that geological inquiry has established of the re-appearance of large *testacea* where lime is present, and their disappearance where it thins out. Now, as we find the other and smaller *testacea*, which are the congeners of these *Pentameri*, at Aymestry, in situations where there is no lime (so invariably, indeed, that throughout a continuous extent of upwards of 100 miles I have, by their presence alone, been enabled to mark *the position* of the limestone), we are led to infer that the animal inhabiting the thick shell of the *Pentamerus*, could only exist in those bays of the ancient sea in which much calcareous matter prevailed.

This limestone of Sedgeley is distinguished from that of Dudley, not only by organic remains and lithological structure, but also by burning to a dark-coloured lime, (hence the name of black limestone) which is of value for the same economical purposes as the limestone near Ludlow, in making most durable stucco and mortar, particularly under water; but if used in agriculture its application must be limited to the light lands, which it enriches by its argillaceous as well as calcareous ingredients.

The limestone of Sedgeley is separated from that of Dudley, by a considerable thickness of shale (the equivalent of the Lower Ludlow rock), which occupies the eastern and south-eastern slopes of the Beacon hill, but owing to the rounded forms of the hills the strata are not well exposed, and their mineral poverty has never led to their being uncovered. The same "mudstone" strata occupy the rising grounds between the Wenlock limestone of Cinder Hill, and the outcrop of the coal, which is exposed on their slopes in the Rookery Lane.

"*Turner's Hill.*"—The Ludlow rocks occupy this small oval hill, lying between Lower Gornals and the Streights. They are surrounded, as at Sedgeley, by thin or slightly productive coal measures, of which a very narrow band, not exceeding two or three hundred paces in width, separates them on the west from the Lower New Red Sandstone of the Himley district, whilst to the east and south they throw off the unproductive carboniferous sandstone of Gornals, in the manner expressed in the section, Pl. 37. f. 2.

The only well-exposed beds are on the western face of the hill, where they consist of impure argillaceous limestone in small concretions, resembling the refuse beds of Sedgeley, in which the *Terebratula Wilsoni*, *Pleurotomaria*, &c. are the prevalent fossils: the overlying beds of flaglike, dirty yellowish sandstone contain a few casts of common Ludlow fossils.

"*The Hayes.*"—The ridge which rises at the Hayes, two miles west of Stourbridge, and is not more than 300 paces in length and 100 in width, very clearly belongs to "Ludlow rocks." Extending from north to south the strata dip from 40° to 50° to the east beneath the adjacent coal

[1] The intermediate places are the Abberley and Malvern Hills, the valleys of Woolhope, Usk, &c.

measures, some coal shafts having been sunk within a few yards of the outcrop of the older rock. The overlying beds, as at Sedgeley, contain the *Leptæna lata*, together with the *Cypricardia amygdalina*. The limestone quarried from the central portion of the rock differs in no respect from that of Sedgeley, except that it is less abundant and of inferior quality, being still more argillaceous. It does not, as far as I could observe, contain the ***Pentamerus Knightii***, but it incloses the well-known shells of the Aymestry limestone, ***Terebratula Wilsoni*** and ***Pleurotomaria***, with others which are common to the whole of the Upper Silurian Rocks, such as ***Productus depressus***, ***Atrypa affinis***, &c.

As the strata are highly inclined, and their southern end is cut through by the high road from Stourbridge to Hales Owen, a better passage is there shown, from the limestone into the lower beds of the Ludlow formation, than in any other part of the district. Like the masses already described, this little boss of Ludlow rocks has been thrust up through the environing coal measures, its southern end advancing nearly to the edge of the Lower New Red Sandstone.

A transverse section across it from east to west exhibits the appearance represented Pl. 37. f. 5.

## *Wenlock* (*Dudley*) *Limestone*. (2nd Formation of the Silurian System.)

This second member of the Silurian System, being of infinitely greater value, has been much more laid open than the upper formation or Ludlow rocks. It rises to the north of Dudley in several elliptical masses, trending in parallel directions from 10° west of north to 10° east of south; the chief of which are the Wren's Nest, the Castle Hill and Hurst Hill. The formation occupies a broader surface on the eastern side of the tract at the town of Wallsall, which is built upon it, and to the east of which some strong ridges of the limestone run along the edge of the coal-field from north-east to south-west. Besides these places where it comes to day, with merely an occasional covering of gravel, the limestone has been discovered by mining beneath the coal-field.

## *The Wren's Nest*. (See ground plan and section, p. 484; and view, p. 485.)

The chief mass of limestone in the district north of Dudley is at the Wren's Nest, which we shall first describe, as it exhibits a full type of the formation. The solid limestone, which is quarried, lies in two bands, separated from each other by shale, the uppermost being 28 ft. 4 in., the lower 42 ft. 3 in. thick.

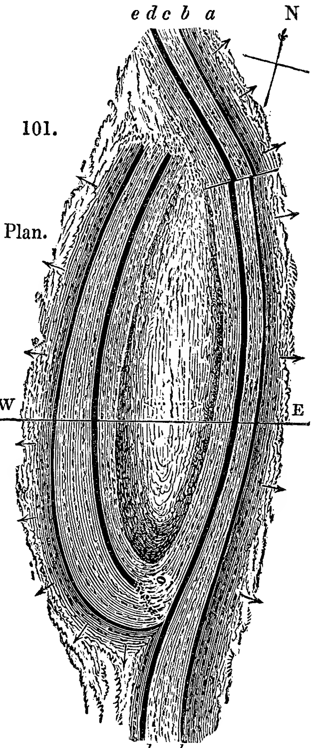
These bands are divided into beds, distinguished by the workmen under the following names.

| Upper or thin measures. (*b.* of wood-cut.) | ft. | in. |
|---|---|---|
| White grey measures (left for roof) | 6 | 0 |
| White grey measures | 6 | 6 |
| Strong hanging stone (darkish colour) | 6 | 4 |
| Top sink | 2 | 7 |
| Pricking, i. e. way-board of shale (blasting layer) | 0 | 2 |
| Bottom sink | 1 | 2 |
| Half yard measure | 1 | 6 |
| Measure under "half yard" | 1 | 9 |
| Bottom measure | 2 | 4 |
| | 28 | 4 |

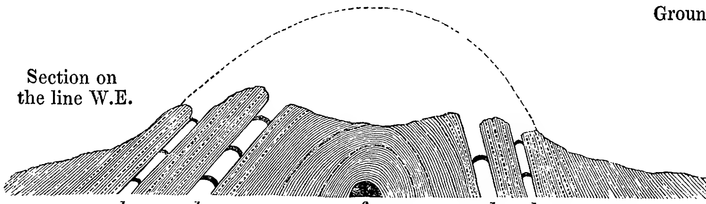
| Lower or thick measures. (*d.* of wood-cut.) | ft. | in. |
|---|---|---|
| Grey measure (left for roof) | 8 | 0 |
| Strong grey measure | 4 | 6 |
| The flints | 4 | 6 |
| Silks measures | 4 | 0 |
| Second yard measures | 2 | 2 |
| First yard measure | 2 | 2 |
| Top sinks | 1 | 3 |
| Pricking, i. e. way-board of shale (blasting layer) | 0 | 4 |
| Bottom sinks | 2 | 4 |
| Black stone | 13 | 0 |
| | 42 | 3 |

*Ground plan and transverse section of the Wren's Nest, the latter double the scale of the former.*

101.




102.



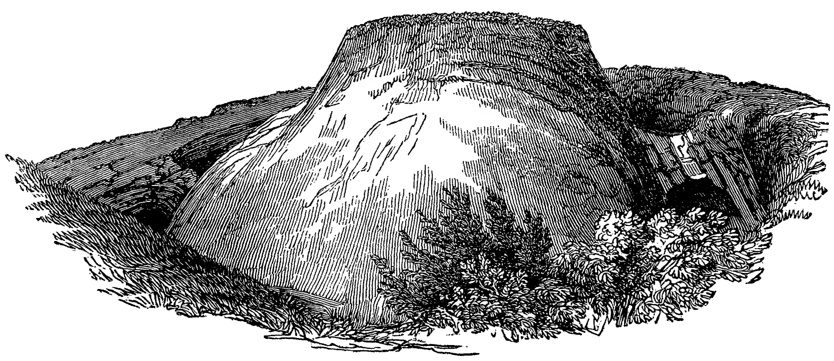

These upper and lower limestones (*b* and *d*) constitute, however, only part of this formation, the remainder, as at Wenlock, being made up of innumerable small concretions of impure argillaceous limestone, occurring at intervals in a matrix of grey shale like the flints in chalk. These concretions are, however, in parts so abundant as almost to constitute one entire calcareous mass, and in districts where lime is scarce they would doubtless be separated from the shale and burnt. Here, however, they are considered as refuse. They are called "bavin," the shale associated with them being termed "rotch." Above the upper limestone (*b*) these impure calcareous beds (*a*) are about 100 feet thick; between the limestones they are about 90 (*c*), and beneath the lower limestone about 60 (*e*), so that the entire mass, including the impure beds, exceeds 300 feet. This is exclusive of the lower part of the formation or Wenlock shale (*f*), which is more than double this thickness; and therefore the whole formation at Dudley may be estimated at 1000 feet or more.

The limestone is lithologically undistinguishable from that of Wenlock, like which it occasionally runs into large concretions, less argillaceous and more crystalline than the mass. These concretions, the "ballstone" of the Shropshire workmen, (p. 210.) are here called "crogs," and they present just the same appearance of interfering with the stratification which has been described near Wenlock.

Organic remains occur at intervals throughout all these beds, but the most beautifully preserved specimens and the greatest variety, appeared to me to lie on the surface of certain thin flaglike beds of the upper limestone.

The elliptical shaped mass of the Wren's Nest is, therefore, composed of an exterior mantle of pure and impure limestone, and a nucleus of inferior shale, in which, as at Wenlock, all calcareous matter disappears. The former rises around the latter at high angles of inclination, i. e. at about 60° on the eastern face and 45° on the western. The purer limestones have been long extracted from the hill itself, as represented by the hollow spaces in the above section; and if the impure limestone or "bavin" had been worth removing, the Wren's Nest itself would long ago have been demolished, leaving only a central mound of shale to mark its former existence. The ridges of "bavin"

($a$, $c$, $e$,) preserve, however, the original features of the hill, and the work of perforation and demolition which has taken place within, can only be judged of by ascending to its summit and looking into the chasms, or still better by traversing the wide and arched vaults from which the limestone has been extracted. Besides that part of the Wren's Nest which rises into a hill, and which has thus been gutted of the richest matter; its bands of limestone are now worked at a much inferior level, by a tunnel driven from the lowest adjoining ground across the heart of the hill, in making which, the same double bands of limestone on either side of a central nucleus of shale, were passed through as in the upper works[1]. Deep shafts have further been sunk upon the dip of the rock, from various points along as well as below this tunnel, and the limestone is brought up and conveyed to the open country by a subterranean canal. The above section across the Wren's Nest, proves that it is nothing more than an elevated dome, the calcareous summit of which was truncated during a period of elevation, when the harder or calcareous strata forming the crest being snapped asunder, the fragments were removed by subsequent denudation. But though an elliptical, elevated mass, the Wren's Nest is not a complete ellipsoid; for a small portion of the exterior margin is broken down, and being deficient in the usual limestone barrier, a natural ingress at one point is obtained to the interior. This occurs at the western turn of the northern extremity, where the eastern side, called Mons Hill, instead of uniting with the western, subsides and feathers off. (See ground plan above.) When viewed from the south, on the contrary, the east and west sides appear to be confluent in a well-turned arch, forming the boldest part of the hill or that near to the town of Dudley[2] as represented in this sketch[3].



103.

[1] My kind friend Mr. Downing of the Priory, to whom I am above all other persons indebted for an acquaintance with the structure of the Dudley district, informed me, that when the tunnel was made, the central shale was precisely as represented in the section, p. 484, i. e. a nucleus with a quâquâversal dip. Without his intelligent directions I should have failed in observing some of the most interesting phenomena here recorded.

[2] The view of Dudley, prefixed to this chapter, is taken from this spot, the Castle Hill being seen on the left hand. In the lithograph, the spectator is supposed to be looking to the south; in the above wood-cut to the north.

[3] This sketch was taken by the Rev. W. Whewell, during a short tour with Professor Sedgwick and myself to Dudley, Wenlock, and the Wrekin, anno 1832.

The solid strata of limestone have not, however, been thus raised and incurvated around a common centre without transverse breaks. In addition to the fissure along the axis of the ridge, there is a fracture of considerable magnitude at the south-south-eastern turn of the ellipsoid (see ground plan), and precisely at that point where the *appearance* of symmetrical curvature of the mass is preserved. Here, the outer band of limestone sweeps round in the wide arch, represented in the previous page, the external part of which (towards the south and south-west) is most expanded, owing to the less inclination of the beds. As these strata approach the south-eastern turn, they rise rapidly in inclination, and seem, on a first view, to be continuous from that point along the eastern face. But this appearance is entirely fallacious; for the *outer* band is there brought into exact allinement with the *inner*; i. e. the trench of circumvallation from which the one limestone has been extracted, seems to be a continuation of the other. On closer examination the anomaly is explained. The inner or lower limestone having been subjected to a very high degree of flexure, has been snapped asunder close to the farm-house of the Wren's Nest (*o*), where the quarries expose great tortion and fracture. By this dislocation, the inner limestone is entirely lost, its place being occupied by shale and bavin. The same stratum, however, on the eastern face, becomes vertical opposite the great cross fracture, and although at one point coincident with the outer band, it does not fold round to the west, but continues its strike to the south and by east, in which direction it has been quarried at a spot called Gabriel's Hole, and has been also cut through by the tunnel of the Dudley canal.

If the Wren's Nest, judging from its hollow axis, be termed a *valley* of elevation, its size and sharply confluent flanks, as well as the materials of which it is composed, have led to peculiar modifications of form, very different, for example, from those of the Valley of Woolhope (p. 428.). The central mass of the latter being of wider area and only slightly curved has not been fractured, and, further, being composed of hard grit has resisted denudation and still remains a dome. (Pl. 36. f. 9.) In the Wren's Nest, on the contrary, the limestone, which doubtless must once have capped its centre, has (owing to the sharp convolution to which it was subjected) been snapped asunder and removed, and thus the soft shale being exposed to denuding influences, a cup-shaped centre has resulted. In this respect, indeed, the Wren's Nest resembles the Valley of Wigmore near Ludlow, where the exposure of the same soft shale has led to a similar, but much deeper denudation. In pursuing the parallel with Woolhope, the reader will bear in mind, that there, the surrounding trenches are those of nature, the perishable strata having been denudated and the solid stone forming banks; whilst in the Wren's Nest the trenches are the work of man, and have been fashioned out of the hardest materials in the hill. We shall hereafter consider the probable cause of the ellipsoidal form of this and the adjacent masses of limestone.

*Castle Hill.* (See lithographic view, beginning of the chapter.)

The Castle Hill has much the same form as the Wren's Nest, and differs only in being narrower, thus exhibiting a less thickness of limestone and less of the lower shale in the centre. The two bands of limestone in this hill vary slightly in detail from those of the Wren's Nest. (See Pl. 37. f. 1.)

Upper or thin measures.

| | ft. | in. |
|---|---|---|
| Grey measures (left for roof) | 4 | 0 |
| Grey measures | 2 | 6 |
| Hanging stone, in very thin layers | 6 | 0 |
| Top sink | 1 | 0 |
| Pricking | 0 | 2 to 3 |
| Bottom sink | 1 | 0 |
| Strong measures | 3 | 10 |
| Thin measures (thin layers) | 4 | 6 |
| | 23 | 0 |

Lower or thick measures.

| | ft. | in. |
|---|---|---|
| Grey measures | 8 | 0 |
| Clunch or spoil, i. e. shale with small calcareous concretions | 4 | 6 |
| Grey measures | 1 | 6 |
| The flints | 2 | 2 |
| The silks | 1 | 8 |
| Second yard measure | 2 | 0 |
| Flint yard measure | 2 | 0 |
| Top sinks | 1 | 3 |
| Pricking (shale) | 0 | 3 |
| Bottom sinks | 2 | 3 |
| Back stone | 10 | 0 |
| | 35 | 7 |

of which 30 ft. 10 in. are limestone.

The excavations made in former times, in quarrying these two bands of limestone, have given rise to the wooded dingles and thickets, so ornamental to the ancient castle which crowns the eminence. Like the Wren's Nest, the southern end is the highest and most perfectly arched.

*Hurst Hill.*

About one mile beyond the northern end of the Wren's Nest is another parallel and similar ellipsoidal mass of limestone called Hurst Hill, the southern end of which is also more arched than the northern, the latter terminating in an obscure elevation called Cinder Hill, where the limestone is without a well-defined western margin. Near the southern end the elevation is most symmetrical; the limestone being thrown up at high angles, passing, on the west, under the Lower Ludlow Rock and Aymestry Limestone of Turl's Hill, and, on the east, under a portion of the Ludlow formation; overlapped by coal measures at the Coppice Meeting House and Ettingshall. (Pl. 37. f. 4.) At the extreme southern point, the ridge being narrow and the angles of elevation very great, the beds are completely broken up and irregularly flanked by the coal measures, which there enter into a small bay in the Silurian rocks. (See Map.) Towards its northern end, Hurst Hill exhibits one ridge of limestone only, which having been formerly extracted in open works, as at the Wren's Nest and Castle Hill, is now wrought by shafts close to the edge of the overlying coal-field, beneath which the calcareous beds dip at angles of 60° to 70°. In Cinder Hill, the limestone is also worked by shafts, and dipping rapidly to the east and south-east, it passes beneath the Lower Ludlow rocks, which have been mentioned as occupying the grounds between this spot and the coal-field. The limestone of Cinder Hill is probably separated from the Ludlow formation of the Beacon Hill by a line of fault.

*Wallsall.*

The Wenlock formation is spread over a much wider space around the town of Wallsall than in any other part of Staffordshire, occupying a width of about two and a half miles, from the Hay Head lime works on the east, where it is overlaid by the detritus of the New Red Sandstone, to the great limestone fault on the edge of the coal-field. Its greatest length is about four miles, from near Bustleholm Mill on the south-west, to beyond Daw End on the north-east. The strike of this mass is north-east and south-west, thus differing essentially from the axes of the ridges near Dudley. Judging from the form of the ground where limestone has been proved, as beneath the town of Wallsall and at Ball's Hill, the rock has been partly thrown up in domes, though the chief masses occupy sharp parallel ridges, trending from north-east to south-west[1], the beds dipping rapidly to the north-west at angles of 40° to 50°. The most prominent of these bands are between the town and the edge of the coal-field.

The limestone worked at Rushall, Daw End and Wallsall is about 11 yards thick, and having been long exhausted at the outcrop, is extracted by shafts, at depths varying from 60 to 100 yards. The clearest relations of this rock to the overlying coal measures are exposed in the sides of the abandoned reservoir between Rushall Hall and Daw End, where ironstone beds and thin layers of poor coal measures, repose at a slight angle of inclination upon the impure limestone and shale ("bavin and rotch") of the formation. Similar relations have been proved along the eastern edge of the coal-field near the Birch Hill collieries, where the limestone has been actually reached beneath some of the ironstone measures. By far the greater portion of the Silurian rocks around Wallsall, particularly in the cold argillaceous tract extending by Delves Green and Botany Bay to the new Railroad, consists of the lower shale[2].

The eastern boundary of this Silurian tract contains a narrow band of limestone, traceable for upwards of a mile, from Ginity Graves to the Hay Head, where it has been long worked in open quarries, which are still productive, owing to the strata dipping at an angle not exceeding 8°. This limestone is very argillaceous, its solid strata not exceeding seven feet in thickness, and even these are divided into seven beds, which are covered by a considerable mass of valueless shale with small

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[1] The masses of limestone nearest to Wallsall are usually covered by gravel.

[2] It is difficult to avoid expressing surprise, that in *this* part of England persons should be found so utterly ignorant of the geological succession of the strata, as to sink for coal beneath the Wenlock or Dudley shale. Recent trial shafts (failures of course) have been made at Delves Green, and exhibit on their sides mounds of shale, charged with fossils of the Wenlock formation. These mistakes occur simply through inattention to the organic remains, with which indeed few practical miners are acquainted. Hence the endless follies we now hear of, such as sinking for coal at Northampton through the inferior oolite, where it is demonstrable, that the unfortunate speculators can scarcely penetrate even the lias formation. Black, bituminous and pyritous shales, resembling beds of the coal formation, are quite enough to lead any common miner to believe that he "smells" the coal, and thus country gentlemen are duped by ignorant men, who often honestly believe what they prophesy. Whether the strata thus resembling coal measures, be a mile above or below the geological position of the carboniferous system, has never formed part of the education of these speculators. (See observations, pp. 328 and 411, note.)

a mass of limestone which proved to be nearly seven yards thick, of exceedingly fine crystalline quality, and less argillaceous than most of the limestone of this tract. On excavating laterally to the south and east, or away from the fault, the limestone was found to extend more or less horizontally, and hence it became an object of prompt speculation, both from its convenient position, and from the excellent quality of the material. When I visited this mine, though the works had only been in progress a few months, they had already cleared out a subterranean chamber of about 100 yards square, and about seven yards in height, supported by rude columns of limestone, the "ties" of the workmen. On descending, I found a large company of miners excavating and exploding the solid rock in a chamber filled with dust, and into which not one drop of water percolated! This appeared the more surprising, since the coal-field which had previously been worked out above our heads, was saturated with copious streams of water descending from the adjacent Rowley Hills. This fault, like most others, is from its compact structure a dam to water, and the shafts being sunk in it were necessarily dry, while the limestone occupying a horizontal position, and being covered by argillaceous shale, the bavin of the workmen, we can easily imagine how the interposition of such impervious materials should close up all access to this excavation; or in other words, *how* the waters of the superjacent coal-field should flow above it, supported by the shale of the Silurian rocks.

On "stripping" the fault towards the trough, the limestone was found to be in contact with a seam of coal which was squeezed downwards, and its surface, as well as that of the limestone, presented the polished slickensides, so frequently observed in similar cases. This coal was supposed by Mr. Downing (who accompanied me in this examination) to be the fire clay coal of the same age as that of Stourbridge, one of the lower beds not usually worked in this part of the district. The portion of the side of this fault which I saw, ranged 15° N. of E., but as the general direction of the sides of the great Dudley trough is nearly N.E., S.W., this must have been one of those zig-zag aberrations so often observed along lines of fractures. Near the fault, the limestone dipped slightly N.N.E., but on being followed on the dip, this inclination even decreased, the beds gradually assuming a dome-like form, into which they are brought by a succession of very small hitches. At the last discovered of these downcasts, the limestone was beginning to incline from 12° to 15°, and as this inclination was too rapid to permit further work upon the dip, it was supposed that a new shaft would soon become desirable. The limestone extracted for burning is subcrystalline, and finely laminated, with rarely any wayboards of shale thicker than a flat ruler, and hence forming two beds only. Both are of gray colours, and are made up of a profusion of encrinites and shells. The rock, indeed, is so compact, that holing places for the gunpowder are found with difficulty, and hence the mining operations are attended with some expense[1]. Having ascertained the lateral extension of this limestone over the area of their property, the successful speculators next bored

[1] The quantity of gunpowder used, when I visited the spot, was half cwt. per diem, and as masses of thirty tons were brought down at a blast, the effect produced was sufficiently sonorous. The dead silence which followed these explosions was quickly succeeded by the din of voices and the clatter of pickaxes. Ventilation is effected by means of air heads driven through the fault.

beneath the present floor, justly conjecturing, that if this was really the same limestone as that at Dudley, there would be a second or lower band; and their enterprise was rewarded by discovering, at a depth of fifty yards, another and thicker calcareous zone, thus completely establishing the identity between the limestone on the hill sides of the Castle Hill and Wren's Nest, and this underground mass, distant *upwards of a mile* from the nearest of these hills.

Whether, therefore, we examine the lower edges and sides of the carboniferous strata of the Dudley field as they are turned up, or penetrate through those central parts where they are thickest, they are found to be incumbent upon some member of the Silurian System. In certain portions of the field, the Ludlow rocks, it is true, emerge from beneath them; but as we approach the Rowley Hills, the Wenlock limestone would seem to be the fundamental rock. Reserving all observations upon the great lines of fault and fracture of the coal-field, until the trap rocks have been described, the history of these Upper Silurian rocks may be concluded by reminding the reader, that the important formations, of Carboniferous Limestone and Old Red Sandstone, which usually accompany and support the coal-fields of Great Britain, are not merely absent, but offer no traces of their ever having existed in this region; all the phenomena inducing us to believe, that the carbonaceous matter was here originally deposited upon the Ludlow and Wenlock formations, or Upper Silurian rocks.

### *Symmetrical Joints of the Silurian Rocks in this district.*

The Silurian rocks of this tract, whether belonging to the Ludlow or the Wenlock formations, are invariably divided by symmetrical joints similar to those described in Shropshire and many other localities, (p. 243 *et seq.*)

Without swelling the work by details, I may select the Wren's Nest as a point to illustrate my views. Let the southern corner of that ellipsoid be examined, just where the strata, receding from the great dislocation near "Gabriel's Hole," are inclined at angles varying from 25° to 30°, the direction of that inclination gradually changing from S. to S.W., without the slightest break of the strata. There, in an ancient quarry resembling a vaulted crypt (see left hand of vignette, p. 485.), and within a space of less than 150 paces, the observer will perceive at least three distinct directions of joints diagonal to the strike, the change occurring wherever there is a perceptible variation in the strike of the beds. Thus, in

| | | | | |
|---|---|---|---|---|
| No. 1. | The faces forming the salient angles trend from | N.N.W. to S.S.E., | and from | E.N.E. to W.S.W. |
| No. 2. | ——— | N. to S. | ——— | E. to W. |
| No. 3. | ——— | N.N.E. to S.S.W., | ——— | E.S.E. to N.N.E. |

Other and similar changes of direction of the faces of the joints take place all round the Wren's Nest with every change in the direction of the strike. I did not examine these joints with *very great* precision, an operation which I leave to Professor Phillips, or any good geometrician who will look into the subject, having myself little doubt, that the very various directions of these joints will all be found to have symmetrical relations to the strike of the strata.

### *Organic Remains.*

For a knowledge of the organic remains of these formations, as found in the districts of Dudley and Wallsall, I refer to the plates and their descriptions; it being sufficient here to state, that those found at Sedgeley, Turner's Hill, the Hayes, &c., perfectly coincide with specimens from Ludlow and Aymestry, whilst seven-eighths of the fossils of Dudley and Wallsall agree with those of Wenlock Edge.

In identifying the fossils of Dudley with those of Wenlock, I am, however, bound to acknowledge, that in certain classes, particularly *Crustacea* and *Crinoidea*, the greatest number and variety of beautiful remains occur at Dudley. (See Plates.)

It has been shown, in alluding to the *Trilobites* of the Upper Silurian rocks, that some of the characteristic species, such as *Calymene Blumenbachii* and *Asaphus caudatus*, are found abundantly, both in the lower part of the Ludlow, and the upper part of the Wenlock formations, though on the whole those species are more abundant in the latter. My belief, till very recently, was that the genus *Homalonotus* was peculiar to the *Upper* Ludlow rock, (see p. 200.) A discovery, however, made while these pages were passing through the press, modifies this inference. The *Homalonotus Knightii* has been found in certain rubbly beds overlying the upper band of limestone, and thus this crustacean must be considered as common to the whole Ludlow formation[1].

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### *Silurian Rocks of the Lickey Hills.* (Pl. 37. figs. 7, 8 and 9.)

The Lickey quartz rock acquired a name among geologists by the description of Dr. Buckland, who fixed upon it as one of the magazines whence the quartz pebbles, so largely strewed over this part of England and the valley of the Thames, had been originally derived[2]. The precise age of this rock, or its position in the geological series, has, however, not yet been pointed out, although some approximation to it was made by the Rev. J. Yates[3]. As the northern end of this ridge of quartz rock (Holly Hill) is not more than three miles from the southern extremity of the great coal-field, and as I have now ascertained that it occupies the place of the Caradoc Sandstone, a lower formation of the Silurian System than is exhibited in any part of the Dudley country, the description of it follows naturally in this place.

[1] One of the specimens of *Homalonotus*, the property of Mr. Blackwell, detected in these rubbly beds at Dudley Castle Hill, being of more perfect form and larger dimensions than any I had ever seen, it is now figured in a separate Plate. (Pl. 7 bis.) The local collections I am most indebted to are those of Mr. and Mrs. Downing, of Mr. Cartwright, and of Mr. Gray. The reputation of Mr. Peyton, of Dudley, as a purveyor of these beautiful fossils, is widely spread.

[2] Geol. Trans., vol. v. p. 506. Old Series.

[3] Geol. Trans., vol. ii. p. 255.

It is necessary, first, to understand the physical geography of this small but interesting tract. A narrow quartzose ridge, composed of the oldest rock, extends from Holly Hill to beyond Kendal End, a distance of about three miles, in a line striking from 15° W. of N., to 15° E. of S. This ridge, of only a few hundred paces in width, and not exceeding four to five hundred feet in height, consists in reality of six or seven elliptically shaped hills, which are traversed by the old and new roads from Bromsgrove to Birmingham. The former descending from near the summit of the Bromsgrove Lickey (960 feet above the sea), passes through the lower ridge near its centre; the latter, avoiding the high hills of New Red Sandstone, winds round in the low grounds between their northern flank and the southern termination of the Clent Hills, and then cuts through the quartzose ridge near its north end, between Rubury Hill and Snead's Heath. The Bromsgrove Lickey Hills, as laid down in the Ordnance Map, are the high hills west of this little ridge. They consist in great part of New Red Sandstone described in a previous chapter; their summits and sides being covered with a vast quantity of the pebbles of the disintegrated conglomerate of that formation, but their northern end, called Lickey Beacon, &c., is a trap rock, being in fact a prolongation of the Clent and Abberley Hills. Correctly speaking, therefore, the quartz ridge should be called the Lower Lickey, though it is not known as such in the country[1]. Small as it is, the Lower Lickey has all the external characters of an old mountain chain, being covered with heath, while the Higher Lickey is verdant to the summit, a distinction which is well explained by the difference in their lithological structure. This lesser ridge is also flanked on each side by thin patches of coal, which lie in the longitudinal valleys that separate the quartz rock from the surrounding hills of New Red Sandstone and trap.

On first examining the tract in 1834, I observed that at two points, on its eastern and south-eastern flank (Colmers and Kendal End), the quartz rock was overlaid by a limestone and shale, which contained some corals and shells of the Wenlock formation. At Kendal End, these strata rise into a small green knoll, which was cut into about twenty-three years ago, and there are still ample remains upon the surface to indicate the age of this deposit, the strata of which are here highly inclined on the slopes of the quartz rock. The solid limestone extracted, did not exceed a yard in thickness, but it was accompanied by small concretions called "*batch cakes.*" The existence of another thin band of limestone was ascertained by sinking for coal at the Colmers (coal moors?) in the depression to the east of the quartz ridge, and between it and the New Red Sandstone of Holly moor. The shreds of coal and shale, which here represent the whole carboniferous series, were easily penetrated; and the sinkings were continued through a thin layer of impure limestone only thirteen inches thick, which, from its appearance and organic remains, I consider to be one of those calcareous courses which underlie the Wenlock shale, and form the top of the Caradoc Sandstone. (Woolhope limestone, see Pl. 36. fig. 9.) It was from this band of impure limestone

[1] These lower hills should certainly have one common term to mark the range of the quartz rock. The southern end, forming part of the demesne of the Honourable R. Clive, M.P., is known as the Cofton Hacket and Bilberry Hills, to the north of which are Snead's Heath, Rubury Hill, and Holly Hill.

and the beds beneath it, that the fucoid-like ramifying bodies were formerly obtained by the Rev. J. Yates, which are figured, (Geol. Trans., Vol. II. Pl. 27.), and I found similar specimens during my visit. After penetrating this limestone, the coal speculators sunk till they were stopped by a hard quartzose sandstone and reddish slaty clay, similar to that which rises on the eastern flanks of the quartz hills.

From these facts I quite convinced myself that the quartz rock of this ridge occupied the place of the Caradoc Sandstone. The completion of a new road from Bromsgrove to Birmingham, however, completely established the correctness of this view, by laying open the northern extremity of Snead's Heath, one of the hills composing the ridge. Here a reddish, siliceous sandstone, from thirty to forty feet thick, regularly bedded, is inclined about 15° to the east, which carries it directly beneath the impure limestone of the Colmers above-mentioned. The upper beds contain many casts of fossils which, owing to the pulverulent nature of the sandstone (made up of rounded grains of quartz with scarcely any cementing matrix except a little iron), can seldom be well preserved, though they are very clearly displayed when fresh quarried. Among them I recognised several well-known fossils of the Caradoc Sandstone, particularly the *Pentamerus oblongus*; and *Heliopora pyriformis*, a coral very abundant in May Hill and other places. These fossiliferous sandstones having in themselves a half fused appearance, form the upper portion of the true quartz rock of these hills, into which they graduate insensibly at Snead's Heath, so that it is impracticable to draw any defined line between the reddish fossiliferous sandstone and the quartz rock. The quartz rock itself is stratified with equal regularity throughout the whole of this little range: in some places plunging to the W.N.W., as in the great masses laid open near the Rose and Crown, in others to the E.S.E., which is the prevalent dip; in a third case it is found thrown over as a saddle, dipping in the same small hill to both sides of the axis; in a fourth it is arranged *en dôme*. A transverse section from the west of Snead's Heath by Colmer's to Hollymoor farm, has the appearance represented in Pl. 37. f. 7., whilst a section across the ridge of the old Birmingham road is shown in Pl. 37. f. 8.

The beds of the quartz rock vary from a few inches in thickness to four feet; and they present all the gradations from the fossiliferous siliceous sandstone above described, to a hard granular quartz grit, and from that into a pure quartz rock[1]. In general, the colour is greyish-white or yel-

[1] Casts of fossils in these beds were noticed by Mr. Yates, Geol. Trans., vol. ii. The same author, in minutely describing the composition of this rock, notices the occasional presence of scattered grains of malachite and of brown hematite. Also, that the common ore of manganese had been collected on the eastern slopes of the hill. I have myself observed grains of black oxide of manganese diffused through the New Red Sandstone in contact with the quartz rock.

It is further well worthy of remark, that the sloping surfaces of this little quartz ridge are in parts covered with a breccia of angular fragments of the rock itself, which seems to have fractured and recemented in place. It is, therefore, strictly a local phenomenon, though it is to be observed that a "brêche en plâce," has been observed on the sides of a similar ridge of quartz rock, the Stiper Stones, which breccia I believe to be of higher antiquity than the adjacent coal measures, of which it seems to form the lower edge or base, p. 285.

## *Trap of the Clent and Lickey Hills.*

On referring to the map it will be perceived, that these hills are of much greater extent than any other masses of similar origin in this region, for they extend from the north of Hagley on the N.N.W., to the Lickey Beacon on the S.S.E., a distance of about six miles. They vary in height from 800 to 1007 feet above the sea, and their outline is very dissimilar from that of the surrounding stratified deposits, their summits being more or less conical, and their sides steep and indented with combs.

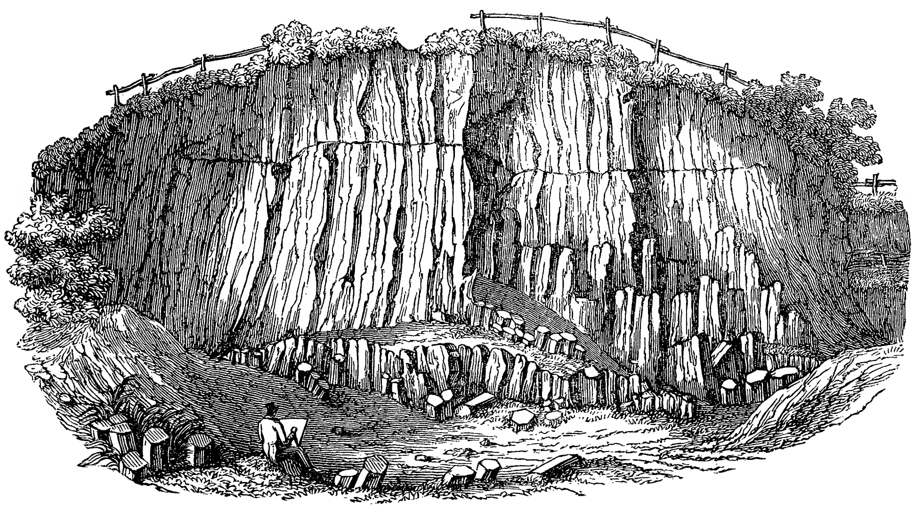
The only rock discoverable, beneath the fine green turf which uniformly covers them, is precisely similar to that described, (p. 138), and which, piercing the coal measures of Bewdley Forest, forms the nucleus of the Abberley Hills. It is a felspathic mass, chiefly composed of brownish-red, compact felspar, occasionally porphyritic, and sometimes passing into a fine concretionary rock. With the solitary exception of the small boss, to which I have already alluded, at the southern end of the Lower Lickey Hills, I am not aware that any solid face of this rock has been exposed; but as it is *the only* stone found beneath the surface, the circumstance of its occurrence only in fragments, by no means invalidates the inference, that these hills are altogether composed of similar materials, (see p. 138[1].)

I have previously shown that certain stratified volcanic grits, lying between these hills and Hales Owen, were formed towards the close of the deposition of the coal measures, and during the accumulation of the Lower New Red Sandstone, (p. 471.) Although similar bedded trap may also have issued from the fissures through which the Clent and Lickey Hills were erupted, it it is clear that the *chief* masses of these hills were emitted long posterior to the accumulation of the bedded trap, which, in common with the coal measures and Lower New Red Sandstone, has been dislocated by the outbursts of the rocks we are now considering.

Trap rocks of peculiar characters, and generally more or less porphyritic, are associated with the lower members of the New Red System pretty generally throughout Europe, particularly in Germany, where their occurrence is so common as even to mark the place of the "Rohte-todte-liegende." In England, it is true, that felspathic trap rocks, passing into porphyry, syenite and greenstone, have been erupted at various and very ancient epochs; but the trap of the Clent, Lickey and Abberley Hills, which we know to be of comparatively recent date, is quite distinct from all other volcanic rocks of the surrounding region. (See Introductory Chapter on Volcanic Rocks, p. 68, and pp. 138, 419 *et seq.*)

[1] At some points indeed, road-stone quarries have been opened, but they merely expose a collection of shivered angular fragments of trap, like the heaps described near the Abberley Hills. Springs rise at very high levels, as is the case in the Malvern Hills, and in one instance almost at the summit of the ridge, (Lickey Beacon). The quartz pebbles derived from the disintegration of the Red Sandstone, and which are heaped up in prodigious quantities on the declivities but never on the summits of this ridge, will be referred to hereafter.

101.



*View of the Pearl Quarry, Timmin's Hill (Rowley).*

## *Trap Rocks of the Dudley Coal-Field.*

The earliest rocks of igneous origin connected with this coal-field, are the bedded volcanic grits to which I have already alluded in describing the strata, p. 471. The other class of trap, which is of subsequent date, appears at various detached points through the coal-fields of Dudley and Wolverhampton. The largest mass in that neighbourhood constitutes the stony hills, extending from Rowley Regis to the southern suburbs of Dudley, having a length of upwards of two miles and a width of about one mile.

These hills range from 15° W. of N., to 15° E. of S., as may be well seen on their western edge, and they are termed in succession, Cawney, Tansley, Warren, Turner, Hailstone, Hawes and Highnam Hills. On their eastern side Cox's Rough and Timmin's Hill are the most prominent points, whilst the church of Rowley is built upon the culminating point of the rock near its southern termination. These hills have long afforded roadstone for the use of the surrounding country, under the name of "Rowley Rag." It is usually a hard, fine-grained, crystalline greenstone, in some cases approaching very nearly to basalt, being an intimate admixture of grains of hornblende with small crystals of felspar and a few grains of quartz. One of the most precipitous faces of the rock is seen at the Hailstone near Rowley, where broad prismatic masses, of a grey colour, rise on the west sides of the hill, and within a few hundred paces of some old coal-pits, the intervening slope being strewed with broken blocks of the greenstone. In this rock the felspar is intimately mixed with the hornblende, but the facets of the crystals of the latter glisten upon fresh fracture.

A most beautiful example of the slender columnar form is seen at the Pearl Quarry in Timmin's Hill, as represented in the above wood-cut, where prisms not less than thirty feet in length and of a few inches only in width, are exposed in a quarry. In Tansley Hill, there are fine examples of convergence and divergence of similar slender prisms. Some varieties of these rocks, it will be

observed, are of different texture from most of the trap rocks described in Salop and South Wales. But besides these basaltic greenstones[1], there are other concretionary and amygdaloidal varieties, some of which contain good specimens of other simple minerals, white calcareous spar being not unfrequent.

The relations of the Rowley Rag to the surrounding coal measures, are, as far as can be collected from any evidence to be depended on, precisely similar to those which have been described in the Clee Hills and other places. The trappean matter probably issued from a principal channel of eruption, and in rising, cut off the coal which approaches to the sides of the hills. This is not clearly seen in any open works, but is inferred from the following data. On the western side of the Rowley Hills, the carboniferous sandstone is tilted from the trap at a very acute angle, whilst the colliers employed in the adjacent pits invariably stated, that the coal became of bad quality, and was cut off as they worked towards the hills. The contorted, elevated, and broken condition of the carbonaceous sandstones in Cawney Hill (the southern suburb of Dudley), where they are actually in contact with the trap, is another good proof of the disturbance created by the intrusion of this rock[2]. Again, on the eastern sides of the Rowley Hills the coal was formerly worked nearly to their edges, but on approaching them, the faults became numerous, and the coal was found to be so deteriorated, that the pits were abandoned. One man of science, Mr. Kier, the able author of the mineralogy of Staffordshire before alluded to, attempted to work coal close to the northern edge of these hills, but he was compelled to resign his undertakings after much expense. Mr. Yates informs us that in one of these works at a considerable distance from the hills, Mr. Kier pierced a mass of greenstone 35 yards thick, and that the coal associated with it was in the state of cinder. This basalt was probably so far distinct from that of Rowley as to have proceeded from an independent source of eruption, for coal was wrought at lower levels and unaffected by basalt between this shaft and the trappean hills. Mr. Smith is the only person I have met with who had been under ground in any of the last trial pits of Mr. Kier. The galleries were driven *towards* the hill, and he assured me that these works had been conducted to a wall of basalt, near which the coal was so brittle, hard, and *valueless*, that the speculation was at once abandoned. Notwithstanding these trials, which demonstrate that the great mass of the trap rock has issued near the area where it now appears at the surface, *some portions of* the volcanic matter may have overflowed the adjoining coal measures in a mushroom form, and in the manner described at the Clee Hills. (See pp.125 *et seq.*) This hypothesis is supported by the circumstance, that the beds of coal recently worked to the south-west of Oldbury, are within a few hundred paces of the trap of Timmin's Hill without symptoms of derangement. Time only can determine whether the basaltic matter which extends at that point as an irregular excrescence from the main ridge of trap, be an overlying mass. If it is so, doubtless the coal might be worked from beneath it, as in the Clee Hills. In the meantime it is proved, that the Rowley trap has pierced the coal measures subsequent to their accumulation, of which we have additional convincing proofs in the state of the coal measures of Dudley Wood which are nearest to the hills; for there the coal is not merely broken

[1] It was this basaltic greenstone (Rowley Rag), which having been fused into a perfect glass by Mr. Gregory Watt, resumed the stony structure upon slow cooling. These admirable experiments, and others of Sir James Hall, completely established the belief that basalt is an igneous product.

[2] Mr. Cartwright, an eminent surgeon of Dudley, to whose collection I shall afterwards advert, pointed out to me certain trap amygdaloids which he had discovered beneath one of the streets near Dudley Church.

up and deteriorated in quality, but its beds are penetrated by lateral wedges of greenstone, which thin out as they recede from the chief centre of eruption[1].

The evidences respecting the source of the trap rocks in other parts of the district are, however, still more convincing; for other insulated masses of trap appear to the west and south of Dudley, and all offer proofs of having been forced up through the surrounding coal measures. The smallest of these masses is the Devil's Elbow, on the edge of the canal below Netherton; a second occurs near Russell's Hall; a third at Cowper's Bank; a fourth at the Fiery Holes; and the fifth, and much the most important, is at Barrow Hill. At the Devil's Elbow, one variety of the rock has a base of felspar, coloured green by chlorite, and traversed by streaks of calcareous spar; a second is an amygdaloid, with large kernels of white calcareous spar; whilst a third, apparently forming part of a dyke, is a crystalline hornblende rock like that of the Hailstone. This outburst of trappean matter serves to explain how the lower and unproductive coal strata have been thrown up to the surface in a dome, on the northern and eastern slopes of which the lower coal measures have been worked out[2].

Near the Fiery Holes, a low cliff about 30 feet high, of concretionary trap has been laid open, and on one side of it is a thin *vertical* bed of altered rock in contact with that variety of trap which the French term "basalte en boules," whilst all the adjacent coal measures are exceedingly fractured. Here the prevailing trap is made up of granular felspar with small concretions of quartz, the mass being tinged green by disseminated chlorite.

Barrow Hill and its dependent rocks is, however, by far the largest and most instructive of these trappean masses. It is composed partly of a greenstone, which on the decomposition of the hornblende weathers to a rusty yellow. Where most homogeneous, this rock has a tendency to a columnar structure; but the chief portion of the hill consists of a dull rotten *wacke*, sometimes amygdaloidal, with much green earth, and frequently bulging out into large concretions. In the old quarries, where the harder rock or greenstone has been extracted[3], the wacke and amygdaloid being left standing, have weathered into very picturesque forms, resembling, in miniature, those pyramidal masses which geologists and tourists who have visited the Hebrides may have remarked on the eastern coasts of Skye[4]. One of these masses is about 50 feet high. They offer in their structure the most convincing proofs of the posterior intrusion of the trap, for their sides frequently exhibit fragments of the sandstone and shale twisted up, sometimes altered into hornstone; and small layers of the coal itself being broken and bent up in the mass of trap. Veins, occasionally

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[1] I have to thank Mr. Best of Corngreaves for a knowledge of this fact. At Hyett's colliery pits, the shaft passed through a thin sheet of basalt three feet thick which occupied the place of the heathen coal.

[2] By a letter received from Mr. W. Mathews, while this chapter is going through the press, it appears that recent excavations have much more completely laid open the trap rocks near Netherton than when I examined the spot. A trap dyke, bearing north-east, runs from the canal, sinking under Netherton Hill before it reaches the church. The tunnel now in progress exposes this dyke for a width of about 60 yards. It is composed of amygdaloidal trap and greenstone, with veins and altered rocks on either side, containing chalcedony and calcareous spar, and on one flank a succession of inclined beds of coal measure, comprising indurated shale, sandstone, and partings, coarse and fine conglomerate, with coal, shale, grit and coaly matter,

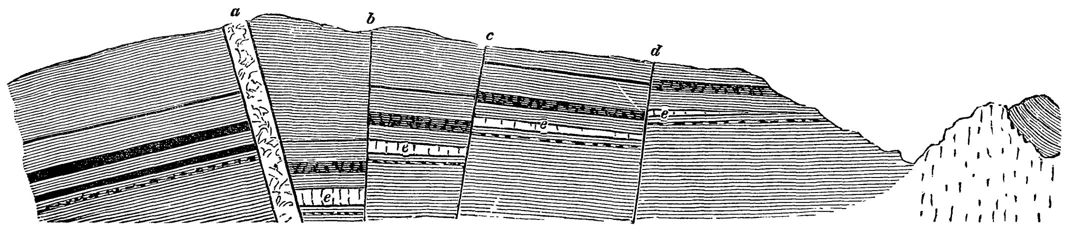
[3] Mr. Yates compares this greenstone with that of Salisbury Craigs near Edinburgh, which contains crystals of augite, and also suggests an analogy between certain basalts of this spot (more or less vitreous) and the pitchstone of Arran. He further notices a point of trap on Brierley Hill which escaped my observation.

[4] The Storr near Portree is the finest example. (See Macculloch's Western Islands.)

containing white crystallized carbonate of lime, quartz, and sulphate of barytes are also frequent. To a certain distance from the edges of this hill, the coal measures are of bad quality and much dislocated; but to the south-east, where no trap appears, there is a large tract of coal, which in the miner's language is supposed to be "in the sound." This is the tract which has been recently worked to the west of the great Brockmoor fault.

The intrusive character of the trap of Barrow Hill is further proved, by the irregular form in which the volcanic matter extends to the north-east by Cooper's Bank, which re-appearing here and there in hummocks, beyond the high road from Himley to Dudley, renders a considerable tract profitless. It is also prolonged in a narrow tongue, for nearly half a mile to the north-west, on the sides of the little brook which flows from Himley Wood, where it may be seen cutting out and dislocating the coal measures. (See right hand of wood-cut below). But besides these courses, which, for the most part, are apparent at the surface, this trap or "green rock" has been projected subterraneously in a tabular mass, nearly conformable to the coal measures, thus:

105.




The band *e* represents the greenstone, which having occupied the place of the heathen coal below the great coal, is seen at different levels, (the effect of faults *b*, *c*, *d*), wedging out to the N.W. The dotted black band, above the greenstone, indicates the thick coal in a coked or altered state. To the left hand or S.E. of a great line of fault (*a*), both the thick coal and the heathen coal lie in regular positions and are *un*altered, no trap rock having been there intruded amid the strata.

Here the trap is, for the most part, an amygdaloidal greenstone, containing kernels of white calcareous spar. Several shafts having been sunk through it, prove that this lateral spur of greenstone occupies the place of the "Heathen coal." It is also ascertained to be wedge-shaped, being twelve yards thick in the shaft nearest to Barrow Hill, and diminishing to two yards in that which is furthest from it. The effect produced upon the coal measures into which this trap has been injected is most remarkable. Not only is the "Heathen coal" entirely cut out and replaced by the greenstone, but the thick coal lying some yards above it, is so altered as to be entirely worthless, being in that coked condition which the workmen call "black and grizzly," i. e. the bitumen is driven off and the mass is of a dull black colour, and much fractured; burning to a red earth or ash, and giving out little or no heat.

The shafts are sunk through the greenstone for the extraction of the "white ironstone" which lies beneath it, (marked by the lower line of dots) and that ore, so far from being deteriorated by the proximity of the trap, is of superior quality. The trap, however, is not in absolute contact with the ironstone, being separated from it by three or four yards of measures, including two or three feet of coal, which, to use the miner's term, is in a "rocky" or indurated state. This tabular wedge of trap has, therefore, clearly been subjected to fractures subsequent to its insertion amid the strata, and to these faults I shall allude hereafter[1].

[1] I am indebted to Mr. Timmins, the intelligent manager of these works, for the information concerning the

### *Trap of Pouk Hill, Birch Hill.*

Though trap is much diffused underground through the northern or Wolverhampton coal-field, being met with in many of the mining works, it shows itself much less frequently, and never in such large masses as in the Dudley district. The only large mass of the rock which appears at the surface is at Pouk Hill, between Wallsall and Wolverhampton, two miles west of the former place. It is there a basaltic rock, very like that of Rowley (composed of an intimate admixture of felspar and hornblende). It rises to the crest of the hill in clusters of four-sided columns, spreading out in a fan-shape and for the most part slightly inclined to the horizon. The lithological characters of this trap have been described by Mr. Finch, in a short notice in the Philosophical Magazine. (See vol. xii. p. 167.) There is little doubt that Pouk Hill is the centre of eruption of much of the trappean matter which to the right and left of it overflows some of the adjacent coal measures, such as the "blue flats ironstone," and penetrates between those beds and the "gubbing stone." At Bentley Forge, a mass of this rock has been laid open, associated with twisted coal, smut, and shale; and in the old clay works opposite this forge, at the foot of Birch Hill Collieries, I found the trap in an overlying position, containing fragments of coal and shale.

At Bentley Forge, the columnar greenstone exfoliates at the angles of the prisms, and shows a tendency to run into spherical concretions, so that it is easy to reduce any of these masses by fracture to a small nucleus. In other places, near Wolverhampton, the trap has the appearance of having been forced in laterally for some distance, between the coal and iron strata, with which it seems for short distances to be regularly interstratified, as in the case before cited.

In the tract now under consideration, the true explanation of such phenomena were long ago pointed out by Mr. Arthur Aikin. As early as the year 1812, that author, being then Secretary of the Geological Society, gave an excellent account (Geol. Trans., vol. iii. Old Series) of a certain mass of the "green rock," exposed in the works of the Birch Hill Collieries; showing from its bulging or irregular form, and its finally wedging out, that it was not a true bed, but simply a dyke, which by its intrusion had altered the sandstone, shale and coal in contact, particularly on the lower surface, the bitumen being driven off and the coal reduced to a cinder. After describing the composition of the trap with his usual mineralogical acumen, Mr. Aikin remarks, that it is penetrated by contemporaneous small veins of calcareous spar, nearly vertical, and that the rock, though highly compact when fresh quarried, is discoloured and falls rapidly to pieces upon exposure. Notwithstanding these clear evidences, most of the iron masters still consider the green rock a regular bed, and believe that it always lies above the *blue flats*. Mr. J. Barker, however, assures me, that its course, position, and thickness are all very uncertain, though generally found just below "the gubbing stone," as mentioned in the section 1, p. 479. At the Chillington Collieries this rock was met with at a depth of 60 yards, overlying the "blue flats" ironstone, the coal in contact being much charred and altered. In parts, however, this apparent bed is only 8 yards thick, whilst in others it expands to 25 and it is therefore proved to be a dyke of lateral injection. To the north of Pool Hays, certain trial shafts having passed through 40 yards of poor coal measures, a mass of this greenstone was met with, which was sunk into to a depth of 53 yards without a change of

effects produced by this lateral wedge of trap, and also for the account of the faults by which it has been affected. The works in question lie to the north of Corbyns Hall, immediately north of the great fault which ranges from Barrow Hill to the Stand Hills, and are close to the western edge of Barrow Hill.

metal. Here it was evident the speculators were sinking upon a point of eruption. This trap of Pool Hays, judging from the specimens which I collected at the mouth of the old trial shaft, was in parts a hard, coarse-grained, grey, granular greenstone with much white felspar; in other parts an amygdaloid, containing nests of zeolite, coatings of crystallized iron pyrites, &c.

### *Principal lines of elevation and subsidence.*

To give an accurate account of all the faults by which the tract around Dudley and Wolverhampton has been affected, would almost complete a detailed history of the coal-field, which is incompatible with the leading objects of this work. I shall, therefore, simply point out the chief lines of dislocation, their direction and connection with the elevated masses of Silurian rocks, and with the points and lines of trappean eruption. It is, indeed, impossible to describe all the dislocations around the *margin* of the field, for as yet we have little information to be relied upon. Enough, however, is known to prove, that the surrounding and overlying Red Sandstone has been subjected to *the same movements as the coal measures*, a fact which, being clearly seen in open work at Sedgeley, is proved in other natural sections round the field, and has recently been substantiated by the sinkings of the Earl of Dartmouth. This conformability of the Lower New Red Sandstone to the coal measures, a fact with which the older geologists were unacquainted, is of considerable theoretical and practical importance. The same phenomenon having been pointed out in the Shropshire coal-fields, pp. 95 *et seq.*, it is probably very general in the central counties, while in the north of England it has been observed by Professor Sedgwick to be of partial occurrence only. In Staffordshire, as in Shropshire, indeed, the mere superficial features of the rocks often warrant such an inference. At the quarries in Sandwell Park, for example, the strata are highly inclined and much broken, dipping to the north-west, and indicating lines of fracture, which trending from the neighbourhood of the Bar Beacon on the north-east, to the end of the Rowley Hills on the south-west, are precisely parallel to those faults near West Bromwich, by which the coal measures have been thrown up from beneath the red sandstone. (See Map.) That these fractures have been caused by the rise, or efforts to rise, of various rocks of volcanic origin, no person acquainted with the subterranean structure of this field can doubt. Lord Dartmouth's works have, indeed, proved the fact as respects the eastern flank of the field[1].

The manner in which the coal is cut off at the edge of the field near Wolverhampton is also specially worthy of notice. The bed there called the "thick coal," together with the *heathen* coal, and the underlying ironstone measures (the *gubbings* and *blue*

[1] Mr. Dawson, whose endeavours have been before alluded to, being anxious to discover the coal measures extending *eastwards* beneath the great mass of red sandstone, caused horizontal drifts to be made in that direction; and in following the coal till it thinned out, a boss or two of hard, unstratified, granular felspar rock was cut through, as represented in Pl. 37. f. 1.

*flats*), instead of dipping under the New Red Sandstone, rise gently as they approach it; nay, further, they taper away and deteriorate in quality, until they are successively intercepted by the line of fracture which brings them into contact with the red ground. As the face of this fault sinks to the west or W.N.W. at an angle of 45°, it follows, that the inferior measures or "blue flats" range 800 yards further to the west than the uppermost bed of coal. (Pl. 29. f. 13. and Pl. 37. f. 3.)

Knowing that the Wenlock limestone has been proved at several points beneath the bottom beds of the Wolverhampton field, and seeing the tendency of that rock to bulge out in other parts of the tract, and to throw the strata into troughs, we can easily suppose, that this anomalous appearance of the coal measures rising against, instead of dipping under the New Red, has been produced, either by an upcast or swell of the Silurian rocks, or by the elevation of some point of trap rock, similar to that observed near Sandwell. This inference, indeed, is countenanced by the structure of the opposite flank of the field near Wallsall, where the Silurian rocks rise to day at angles of 40° to 50°, and trending from north-east to south-west, constitute what is termed the "great limestone fault"; which throwing off the coal measures, as represented (Pl. 37. f. 3.), may there be called the natural edge of a basin. Again, as the elliptical-shaped Silurian masses of Sedgeley, the Wren's Nest, and Dudley rise in steep ridges and domes, the coal measures on their flanks are naturally cut off, and in several cases the coal is also bent up on their lower edges at high angles. These sudden expansions of the inferior rocks, have necessarily produced great flexures in the overlying coal measures, throwing them into irregular troughs of unequal sizes. It must, however, be always recollected, that when viewed as a whole, the tract, so far from being a basin, is merely made up of undulating broken masses, the sides of which are lost on all sides beneath the New Red Sandstone[1].

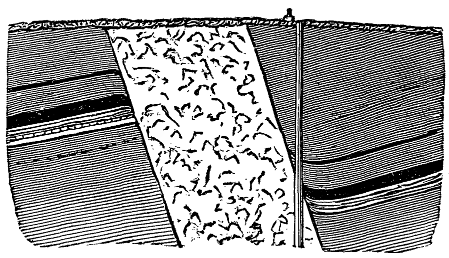
The irregular elevations of the inferior rocks are necessarily accompanied by dislocations, some of which extend for considerable distances through the adjacent coal-field. The most powerful faults in the richest part of the Dudley field range from north-east to south-west the direction of its major axis. Two of these, running parallel to each other, produce a deep and narrow trough of coal of 84 yards in width, the base of which is 100 yards beneath the thick coal on the south-eastern side, and 80 yards beneath it on the north-western. The edges of this trough coincide precisely with the direction of the axis of elevation of the Wallsall limestone, and the result is, that on the chief upcast side, the same limestone throws up the coal measures, thus proving that the forces which determined the protrusion of the Wallsall ridges, produced also the subterranean upcast of Dudley Port. The transverse section (Pl. 37. f. 1.) explains the

[1] I am the more desirous of directing attention to these general relations of the coal-field, because Dr. Buckland in his Bridgewater Treatise has given a section by Mr. Jukes, Pl. 65, which though true as respects a portion of this tract, ought not to lead to the belief, that this coal-field, like ordinary coal basins, is on the whole supported on its flanks by older rocks. (See my sections, Pl. 37. figs. 1 & 3.)

succession of the principal faults which traverse one of the richest portions of the field, passing the Dudley Port trough, and crossing from Christchurch on the east by Dudley to King's Swinford on the west.

The faults to the west and south-west of Barrow Hill have been already alluded to. They there traverse a rich tract, which in former times was supposed to be entirely void of coal, because it was bounded by one of these great dislocations, called the Brockmoor fault, which, proceeding from the southern end of Barrow Hill in a curvilinear course, strikes to the south-west.

One of the most interesting faults of this tract proceeds from the north-western flank of Barrow Hill, trending to the Stand Hills near King's Swinford on the western edge of the coal-field, in a direction nearly north-east and south-west. This fault is about 140 yards wide and is an upcast to the south-east of about 90 yards, the sides being inclined from 80° to 90°, as represented in this wood-cut[1].




106.

The manner in which the lower edges of the main coal are twisted up against the rise side was ascertained by actual work, and it is important to remark that the stratum (*h*) beneath the productive measures, was a mass of red ground with conglomerate, in which a horizontal road was driven for 55 yards. The chief point of interest in this dislocation is, that it ranges precisely in the direction of the chief spur of trap rock which proceeds from Barrow Hill, while three other minor faults (to which I have alluded as dislocating a wedge of trap in common with the coal strata), are also parallel to it.

Another fault, contiguous to the great one of Barrow Hill, seems to unite with it near the Stand Hills, and trending by Shutend furnaces, forms an acute angle with the Barrow Hill fault. (See Map.)

But although the north-east and south-west direction is the prevalent line of fissure through a large portion of Staffordshire, extending its influence northwards from Wolverhampton and Wallsall to Penkridge and Cannock Chace, and southwards into the Dudley field, not only as far as Dudley Port, but even into the south-western angle of the field between King's Swinford and Stourbridge, it is met, as we have seen, by another great line of disturbance in the environs of Dudley, which in the first instance proceeding from 10° and 15° west of north, to 10° and 15° east of south, (Sedgeley and

[1] I owe this section to my friend Mr. W. Matthews of Green Hill, one of the best-informed iron masters of the district.

Dudley,) elevates certain detached masses of Silurian rocks. To the south of Dudley, the same line, bending 5° or 10° more to the east, is still more powerfully marked by the outburst of the great trappean ridge of the Rowley Hills. An axis of elevation, proceeding from the southern end of these hills, is further traceable, through the arched and anticlinal forms of the tufaceous conglomerate and sandstone east of Hales Owen. (See Map.) It is also on this great and long line of dislocation, or on a fissure precisely parallel to it, that the Silurian strata of the Lower Lickey have been elevated, the short interval of about three miles, which separates those rocks from the dislocated coal measures, near Hales Owen, being concealed by the Lower New Red Sandstone. And, lastly, the trap of the Clent and Lickey Hills, has also been erupted on the same parallel, as the axis of the Dudley and Rowley Hills and the Lickey quartz ridge.

Looking, therefore, at the general configuration of this tract, extending from Cannock Chace to the Lower Lickey Hills, we see that the Silurian rocks which support the coal measures, have been thrown into *divergent directions* by two separate lines of elevation; and these divergences have, we presume, been determined by the eruptive forces which evolved the trap rocks, because we find the latter bursting out and dislocating the strata on both these lines. We might naturally expect, that the points of meeting of these divergent lines should be marked by peculiar phenomena, and such is the case; for the singular domes or ellipsoids of elevation in the Silurian rocks north of Dudley, where the strata have undergone every degree of curvature and fracture, are situated exactly where the lines of eruption cross each other. Here, it is presumed, the heat and gaseous accompaniments of volcanic operations, unable to escape, have been the chief cause of these inflated forms, as well as of those of similar shaped and altered ridges of Caradoc sandstone near the Lickey Hills.

But besides the great lines of dismemberment which have determined the outline of the carboniferous tract, and have partially thrown up the Silurian rocks once subjacent to it, there are many considerable *transverse fractures*, or, as they are called, east and west faults. Some of these have already been alluded to, both north of Wolverhampton and between Dudley Port and Wednesbury. The "Lanesfield fault," one of great magnitude, proceeds from near the northern termination of the Sedgeley Hills, almost to Wednesbury, a distance of about three miles. This fault, it will be perceived, ranges precisely from the point where the north-east and south-west line of elevation is met by that which strikes to the east of south, and is, therefore, just such a cross fracture as might naturally take place, during the heaving up of solid masses into divergent directions.

That transverse cracks would follow from elevations of tracts "*en masse*" has recently been sustained upon mathematical and mechanical principles by Mr. Hopkins[1]; and

[1] Trans. Cambr. Phil. Soc., vol. vi. p. 1. The memoirs of Mr. Hopkins are full of profound mathematical and mechanical knowledge, and may eventually lead to an explanation of some of the most recondite principles of geology.

the cross fractures in this coal-field seem to afford a good illustration of a portion of the ingenious reasoning of that gentleman; for whilst the Lanesfield and Birch Hill faults are nearly at right angles to the north-east and south-west strike of the strata which they traverse, so are the Pouk Hill and other faults transverse to the other axis, which in the southern district trends from Dudley on the N.N.W. to the Lickey quartz rock on the S.S.E. In fact, these cross fractures are varied exhibitions of the same phenomena, which in previous chapters were described as having produced the transverse valleys of dislocation.

One of the most important of the faults cuts off the 10 yard coal-field to the south of Corngreaves, and brings it abruptly into contact with the Lower New Red Sandstone. This, which may be called the "Corngreaves fault," is undeniably more worthy of attention than any other east and west fracture; for the 10 yard coal has recently been proved to range up to it in undiminished thickness and of excellent quality. Hence, there is every reason to believe that the productive coal-field will be hereafter worked beneath that portion of the tract, marked Lower New Red Sandstone in the map, which extends from Hales Owen to Old Swinford. (Lord Lyttelton's country[1].)

All the great transverse faults of this field with which I am acquainted, must have been produced *after* the insertion of the trap rocks amid the carboniferous strata. This is proved, by finding certain masses of greenstone, which have been shifted up and down with the coal and iron beds; so that the ends of any one of these masses, instead of being continuous with other portions of trap, abut abruptly against coal measures, and when thus lost, are found again at a different level but having the same relative position in the strata. This has been already shown on the western side of Barrow Hill, where a wedge of greenstone having been inserted amid the coal measures and having entirely charred the coal, the whole mass has been subsequently broken up by transverse faults as in the diagram, p. 500.

Another clear example of this phenomenon occurs on the eastern slope of the Birch Hill Collieries, whence a double line of fissure proceeds in a somewhat zig-zag line by Bentley Lodge to Pool Hays. On the outside of the most southern of these fissures "the blue flats" or bottom beds of the field are thrown up to near the surface, without any cover of trap; whilst to the north of it, the same bed of ironstone has been worked at the depth of 180 yards, the shafts passing through a mass of greenstone immediately above the bottom coal. The measures there occupy a trough of upwards of 100 yards in width, and lie in nearly a horizontal position, when they are met by the second line of fissure, and the whole of these are upcast from 40 to 50 yards, the mass of greenstone being shifted into the same relative place between the 4 foot and the bottom coal which it occupies in the lower trough.

[1] I shall most sincerely rejoice if this anticipation is realized, and that the family of the late Lord Lyttelton should benefit by the hint of one, who cherishes a grateful recollection of the pleasant days spent at Hagley Park, in the company of that highly accomplished nobleman.

Mineral springs occur in the southern part of this coal-field. The most noted is a collection of small wells which rise upon Pensnet Chace, and are known by the name of Ladywood Spa or Cradley Salt Well[1]. In noticing this and two other saline springs, the one at Brierley Hill, the other on Cradley Heath (Rowley), Mr. Yates has well observed, that they are situated nearly on a line, running east and west across the coal-field, and coinciding with the position of a fault which extends to the south end of the Rowley Hills. I have, therefore, little doubt that these springs owe their origin to disturbances, which in dislocating this tract have altered the strata, from which the mineral waters rise to the surface through transverse cracks or fissures. (See pp. 155, 252, and 334.)

In reviewing the relations of the Dudley coal-field to the rocks of volcanic origin, it must be remembered that the district contains two classes of trap;—the one regularly interstratified and contemporaneous with the coal measures, the other injected into the strata posterior to their consolidation. The former is represented by the trap-tuf, and volcanic conglomerates of Haydon Hills, Corngreaves, and Hales Owen; the latter by the basalt, greenstone, and amygdaloid of the Rowley, Barrow, and Pouk Hills, &c. Other phenomena teach us, that this coal-field has been subjected to violent dislocations, some of which have clearly taken place *since* the last irruptions of volcanic matter; for it has been plainly shown, that the injected masses of trap have been broken off and heaved up and down, in connection with the beds of coal with which they had previously been solidified.

Thus, while the dismembered condition of this tract explains, how the sedimentary deposits must have been dislocated, before the volcanic products could have risen to the surface, or spread through the strata in wedge-formed masses, we also learn that the region was long after the theatre of violent earthquakes (the usual followers as well as precursors of volcanic action), which have doubtless caused the great faults or fractures.

Let it be always recollected, that such fractures have a direct practical bearing upon the development of the mineral wealth of England; for as it has been shown, that the carboniferous strata of Shropshire, Staffordshire, and Worcestershire are very similar, and as we know that such strata, so far from being *lost* at the old boundaries of the coal-fields, are in general merely cut off by faults, and are continued beneath the New Red Sandstone, it is highly probable, that coal measures may exist in intermediate tracts, now covered by that System. At all events we know, that where volcanic action has been rife, the carboniferous strata *have* been forced upwards through a crust of red sandstone; and hence we infer, that in those tracts where upheaving forces have not acted, and the red sandstone lies in undisturbed troughs, it *may* cover coal-fields capable of being advantageously wrought. But it must be remembered, that as some of the coal-fields thus exposed are profitable and some valueless, all attempts to

[1] Mr. Cooper's analysis of the Ladywood Spa gives in a wine pint, carbonic acid 2·1, azote ·4 cubic inches: muriate of soda 49·75, muriate of lime 19·07, muriate of magnesia 7·50, muriate of iron 0·13, carbonate of lime 1·50, carbonate of magnesia 1·70, carbonate of iron ·90.

find good coal seams beneath the New Red Sandstone, must, to a certain extent, be speculative, though there may be little doubt of the extension of carboniferous strata. The Dudley, the Titterstone Clee and the Coal Brook Dale fields are examples of productive; the Brown Clee, Kinlet, Shatterford and Abberley of unproductive measures.

Reverting, however, to the more cheering prospect of the two, and believing that beneath the tracts of New Red Sandstone surrounding the coal-fields, there may exist a due proportion of thick and valuable, as well as of thin and profitless coal seams, let me advise the proprietors of such tracts, before they embark in mining, to ascertain the exact geological position of the red land on which they live. If it should belong to the upper or even to the middle portion of the New Red Sandstone, they would do well to desist. If, on the contrary, it should belong to the *Lower* New Red; and above all, if the spot be not very distant from the edge or boundary of a good coal-field, then let the trial be fearlessly made. But the speculator must bear in mind, that coal, like every other mineral substance, is distributed in layers of variable thickness, and may therefore rapidly attenuate as well as suddenly expand within a very limited area. A remarkable example of this phenomenon has been exposed by the works at West Bromwich. This enterprise has, indeed, completely confirmed the geologist's view, by showing the existence of a carbonaceous formation beneath the New Red Sandstone; but, we must fairly acknowledge, that as an experiment to prove the existence of a good *commercial coal-field*, extending towards the town of Birmingham, it has for the present failed. In the meantime, the shafts of Lord Dartmouth, being nearly one mile distant from what was anciently supposed to be the edge of the coal-field, where the 10 yard coal is cut off by a fault, there is every rational ground for believing that the work, when followed to the west or towards the known coal-field, will amply repay the outlay of this spirited enterprise. (See Pl. 37. f. 1.)

In conclusion, it may be observed, that as no thick stratum ever had an abrupt termination (like that exhibited on the sides of the boundary faults), so it is demonstrable, that whenever the coal is thus "lost," in contact with rocks of younger age than itself, it is lost only for a short distance, and is always to be regained at a lower level by penetrating the younger deposit.

The application of this principle to certain tracts on the northern and eastern sides of the coal-fields of Coal Brook Dale, and generally around the Staffordshire and Worcestershire coal-fields, must be obvious to all, who have perused the preceding pages.

I press the consideration of the extension of coal measures beneath the New Red Sandstone of the central counties, because, though absolutely essential to a correct calculation of the probable duration of British coal, it has been entirely omitted in our national estimates[1]. Hence political economists may be led to appreciate the value of geological inquiry.

[1] See Report on the state of the Coal trade, ordered by the House of Commons to be printed, 13 July, 1830.

# CHAPTER XXXVII.

## SUPERFICIAL DETRITUS.

*Introduction.—Division of the subject of superficial detritus.—Drifts comprised within the hydrographical region of Siluria.—Ancient or submarine condition of this region.—All its ancient drift shown to be of local origin, and caused by local agency of tides and currents, influenced by elevations of the bottom of the sea.—Such drifted matter found on slopes descending from elevated ranges, occupying both lofty and low positions.—Enormous extent of ancient denudation in the transverse valleys now watered by the tributaries of the Severn.—Distinctions between marine drift and fluviatile accumulations.—Recapitulation.*

### *Local Drifts within the region of Siluria.*

THE description of all the rocks of aqueous or igneous origin, and the account of their various dislocations being completed, I shall terminate the history of the physical geology of the region, by pointing out the nature of the various loose materials which encumber the surface of extensive tracts, but which could not be intelligibly treated of, without a previous explanation of the nature of the rocks from which they were derived, and of the operations which led to their distribution.

This subject is naturally divisible into two classes. The first includes all those coarse and sometimes far transported fragments, to which some geologists apply the word "diluvium," but which to avoid misconstruction I designate drift[1].

[1] "Diluvium," as used by Elie de Beaumont and the modern foreign geologists, means precisely what I term "drift." In England, however, where the results of distinct physical operations or various mutations of the relative levels of sea and land, were formerly merged under one head, and in some instances forced into accordance with the effects of the deluge which destroyed the human race, most geologists have abandoned the use of a word which has been so misapplied. He who connects diluvium with the Deluge of Holy Writ must contend, that all such detritus was produced in one short period. But geologists having now completely ascertained, that each region of the earth has its own superficial diluvia, produced by distinct and separate action, the unambiguous word drift is proposed, which when preceded by the name of the tract whence the materials were derived, expresses at once the intended meaning. Hence, "Silurian drift," "Cumbrian," (or as respects England) "Northern drift," "Scandinavian drift," &c. &c.

Of this drift, the region contained in the map presents three distinct varieties, two of which may be termed local, the third foreign or transported from a distance. The drift of the high lands of Siluria is of the earliest date, and was produced by the elevation of the older rocks. The next in age arose from the upcasts of the various coal-fields, and the third or most modern drift is that, which covers large portions of the central counties and contains bowlders of northern granite. All this detritus was accumulated beneath the sea during successive epochs.

The local drifts will be first described, and the most recent or northern drift will chiefly occupy the next chapter. It will, however, then be shown, that the far transported detritus, though generally overlying, is sometimes mixed up with, and not easily separable from, the local debris.

The second class of alluvia includes all the deposits formed in lakes and river courses, since the final elevation of the districts from beneath the sea; also the masses of travestine formed by calcareous springs, and the various results of atmospheric action.

These phenomena will be described in two other chapters, after the submarine drifts have been disposed of; though for the sake of illustration, some examples of the two classes will be occasionally considered together.

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*Local Drift within the region of Siluria.*

All the loose detritus which covers the surface of large tracts in South Salop, the north-west of Worcestershire, the whole of Herefordshire, and the adjoining Welsh counties, may be called local; because it has been derived, either from mountains forming the north-western limits of the country, or from the disintegration of rocks, occupying the very districts where the materials are found.

This region, therefore, being free from all distantly transported detritus, presents a class of phenomena distinct from that which is exhibited in those parts of the kingdom, where the surface is covered by accumulations of materials derived from remote countries.

Now, as the drifted matter is of local origin, so we conclude that the action of the bodies of water which produced it, must also have been local, and totally unconnected with any vast or general deluge, even confining the application of the word "general" to a small portion of Europe.

Another important inference derived from the phenomena connected with this drift, is, that the high combs, as well as valleys in which it abounds, must have been permanently under water; for it is plain, that they could have been modelled into their actual forms only, by the action of a large body of water overspreading their entire area; and this mass of water could not have existed unless the valleys were then beneath

the level of the sea. The nature of the excavation indicates also the action of water differently propelled at different times, perhaps by tidal currents, the directions of which were determined by local causes, as the deposition of banks of sand or partial elevations of the bottom of the sea.

The tract thus exempted from foreign drift, is, in great measure, circumscribed by the course of the Severn[1]. This most magnificent of the British rivers, rising in the mountain of Plinlimmon, escapes from Wales into the plains of Shrewsbury by a northern course, and traversing a ridge of Silurian Rocks and coal measures at Coal Brook Dale, is deflected southwards to the sea, passing within a few miles of the Abberley and Malvern Hills, the eastern limit of the tract under review. The drainage of the country bounded by the Severn, is effected by a number of its tributaries, which springing from the mountains of Shropshire, Radnorshire, and Brecknockshire, descend into the lower districts of England by south-easterly courses, at right angles to the direction of the chains which they intersect. It has been shown, indeed, that these streams traverse the mountain ridges in channels produced by cross fractures of the strata. The three principal rivers are the Teme, with its chief feeders the Onny and the Clun; the Wye, with its tributaries the Lug, the Ithon, and the Irvon; and the Usk. All these streams flow from north-west to south-east, through ridges of Silurian rocks and Old Red Sandstone, and empty themselves into the Severn.

The Towy or great Caermarthenshire river, also the Taaf and the Cleddau streams to the west of it, run southwards and south-westwards into the Bristol Channel through lateral depressions in the Silurian and other rocks of South Wales; and though flowing in divergent directions from the Teme, the Wye and the Usk, they conform to the same rule and have been regulated by the same cause. In short they all pass through fissures, transverse to the direction of the strata; for it has been shown, that in Caermarthenshire and Pembrokeshire, an east and west strike being predominant, the great transverse breaks or lines of drainage trend from north to south. (p. 406.)

Within the area watered by these streams, not only the valleys but various elevated combs, and basin-shaped cavities as well as the slopes and escarpments of hills, are

[1] In the annexed geological map no attempt has been made to distinguish by any peculiar colour the fine alluvium from the coarse drift, it having been found impossible so to do without conveying erroneous impressions. It was, in fact, impracticable to mark every spot in which gravel has been lodged so as to distinguish marine drift from fluviatile and lacustrine gravel. The region covered by Welsh and local detritus *only* is, however, pretty nearly defined on the map, by the outline of the Cambrian, Silurian, and Old Red Systems. On the other hand, the country coloured as New Red Sandstone, though also partially occupied by local detritus, is that over which the northern drift has been spread. If the reader will convey his eye over the whole of the region coloured in the map as New Red Sandstone and Lias, and also over those coal-fields which are *surrounded* by New Red Sandstone, he at once sees the region which has been the recipient of the northern *or foreign* drift. On the contrary all the country to the west of the New Red Sandstone is exclusively covered by local drift. The river courses mark the chief channels in which ancient deposits of lakes and rivers have been accumulated.

strewed sometimes with bowlders, coarse gravel and clay, at others with finely comminuted materials, the whole, however, being invariably of *local* origin. Much of the coarse detritus is lodged upon the western limits of the Old Red Sandstone, and is found always in situations where the bowlders may be traced, within the space of a few miles, to their parent rocks. Thus, for example, in the neighbourhood of Kington, the large blocks of syenite, hypersthene rock, or other varieties of trap, and of Cambrian, or Silurian Rocks which are strewed over the surface, have been rolled off from the adjoining hills of Old Radnor, a tract which has been shown to have been formerly much subject to volcanic action, (Pl. 33. f. 4.) whilst in the finer gravel are found many of the well-known fossils of those associated Silurian rocks, which here dip under the Old Red Sandstone. Wherever there have been violent elevations of the strata, we invariably find these accumulations thickly spread out, obscuring the junctions of the various deposits. Striking examples occur, along the outline of the Silurian rocks, from the Ludlow promontory and the gorge of the Onny to the environs of Kington. To the south-west of Kington the lower beds of the Old Red Sandstone, resting upon the slopes of the Ludlow rocks, have been the subaqueous water-shed, down which the coarse detritus has been swept, and thenceforward to the south-western termination of these groups, their junctions being free from such detritus, are clearly defined. In the neighbourhood of the Hay and facing one of the chief transverse gorges of the Wye, mounds of coarse rubbish are piled up against the escarpment of the cornstone or middle group of the Old Red Sandstone. On the rising grounds between Hay and the Sarnesfield Hills, the surface of the lower beds of the Old Red Sandstone is loaded with this coarse drift, which renders whole parishes arid, as indicated by the appellations of "Rough Moors," "Labour in Vain," &c. This detritus may strictly be termed local, either being made up entirely of fragments of the lower beds of the Old Red Sandstone itself, or derived from the adjacent Silurian rocks, whose frontier is distant only five or six miles. So local, indeed, is this detritus, that it has not even travelled down the slope of these hills into the rich contiguous valley of Weobly, still less has it been carried to the escarpment of the cornstone of the Old Red Sandstone, though these situations lie exactly in the line of the drift. In passing to the south-east, in proportion as you recede from this frontier of Silurian rocks the coarse bowlders disappear, and the gravel becomes more and more finely comminuted. At Luston, near Leominster, and two miles from the boundary of the Silurian rocks, the following section may be observed in one of the gravel pits.

1. Red stiff loam. 2. Fine reddish sand. 3. Sand and pebbles of Silurian rocks, quartz, trap, &c. irregularly bedded. 4. Fine red sand. 5. Strong coarse gravel made up chiefly of fragments of Wenlock and Ludlow rocks, with many of their included fossils. 6. Fine white sand. 7. Fine red sand. 8. Fine sand with small pebbles. 9. Coarse red sand. 10. Sand with bowlders of Silurian rock, some as large as eighteen inches by four, so little rolled as to preserve the sharpness of their edges.

This section, with many others along the escarpment of the cornstone formation,

indicates a method of accumulation precisely analogous to that in which gravel, sand, and bowlders are now heaped together on sea shores or in estuaries; while the change in the nature of the drifted materials proves that the currents which propelled them, flowed from the north-west.

Advancing from the Welsh frontier and passing to the south-east, even the fine gravel of the Welsh and Silurian Rocks disappears, and before we reach the central and eastern parts of Herefordshire, the surface of the rich red marls is, for the most part, free from *all transported matter*.

This arrangement of the coarse gravel on the north-west, and fine towards the south-east, demonstrates, that the drifts which affected the surface of the great trough of Herefordshire proceeded *from* the former direction. When we attentively examine these heaps of gravel, we find, however, that the more finely comminuted varieties, alternate so often with sand, and are so different in composition, that we cannot but attribute their deposit to long-continued periods of subaqueous accumulation, and not to any sudden transitory rush of waters. The plain between Leominster and Aymestry, being so near an important elevated mass, the Ludlow promontory, is, as we might suppose, much encumbered with this detritus, and similar heaps are lodged at various heights upon the edges of the cornstone escarpment in the neighbourhoods of Tenbury and Leominster. These accumulations are by no means confined to the vale, like the example cited at Luston, but are equally spread out in high situations, where no streams can have flowed since the present configuration of the land, and also on the sides of low, broad, valleys, through which the principal rivers pass from the north-west to south-east.

In ascending any one of the transverse valleys, beyond the limits of the Old Red Sandstone, the distribution of the coarse and fine detritus also shows a similar transport from north-west to south-east. That this has invariably been the direction of the currents throughout the country under review is proved, by never detecting fragments of the rocks which lie to the south-east in any part of the north-western region, all the broken and drifted materials being lodged to the south-east of each particular ridge, and never to the north-west.

Let us first look to the valley of the Teme. This river has its source in the high lands of Kerry Hill, west of Knighton, to which place it glides down through the soft sandstone and flag of the Ludlow rocks. In all that high region, there is not a bowlder, which cannot be referred to some rock upon the west and in the immediate vicinity. Whatever is the composition of the small shingle or modern alluvia carried down by this stream, such are the alluvia of ancient date, though the latter are coarser and placed at higher levels on the mountain sides. Let the reader specially dwell upon this important fact.

Again, the Onny, a tributary of the Teme, presents similar phenomena, accompanied by still stronger proofs of the agency of a body of water no longer in action. This sluggish

river, which descends at an angle not greater than that of the Thames above Oxford, wanders for the first few miles after it quits the hills, in a plain of deep, coarse gravel, filled with large bowlders of every variety of trap, derived from the adjacent hills of Cornden and Lindley, and of quartz rocks from the Stiper Stones. This coarse gravel is not merely strewed in the direction of the Onny, but extends also from the depression in which is situated Bishop's Castle, into an upland comb called Prolimoor, filling the cavity between the mountains, above-mentioned, and the Longmynd. All this coarse detritus, however, can be traced up to the north-west, and is therefore one of the proofs alluded to, of the former agency of water; and hence we may infer, that it was distributed upon the sides of that elevated region, which has been shown to have been peculiarly agitated by volcanic action. Examining the valley of the Onny in the vicinity of Wistantow, a few miles further to the south-east, we find the same materials, but in less quantity and much more finely broken. There, however, the mixture contains in addition fragments of the adjoining mountains of the Longmynd and Caer Caradoc. Arrived in the plain north-east of Ludlow, where the Onny and the Teme unite, and having traversed the ridges of Wenlock limestone and Ludlow rock, we find the accumulations which are so thickly spread over the plain, still further enriched by fragments of these fossiliferous strata. Rounded fragments of all the varieties of trap and Lower Silurian Rocks, including much quartz rock, are mixed up with fragments of the Upper Silurian Rocks of Wenlock edge and of the Mocktree Forest. Beyond Ludlow and still further to the east, the same materials have been carried only a few miles towards Tenbury, some fragments of the basalt of the Clee Hills being added as soon as the line of drainage has passed that mountain. Further eastward this gravel gradually becomes finer, and below Tenbury we lose all traces of it, the whole of the broken materials thence to the Abberley Hills, having been exclusively derived from the spoil of the adjoining rocks of the coal measures or Old Red Sandstone[1].

The manner in which it is supposed, that some of the low alluvial terraces in the valley of the Teme have been formed, will be explained hereafter.

In describing the matter which has been transported in the same direction as the Teme, it is not to be understood that the mere valley or bed of the river is implied. I allude on the contrary to those heaps of coarse sand, gravel, and clay, which are occasionally spread over hills as well as plains, and which, in some of the hills above Tenbury, are lodged at heights of several hundred feet above the river. These materials are in some parts so arranged, as to convey, like those at Luston, an impression that they were accumulated throughout long periods. The largest bowlders are usually on the surface on the higher grounds south-east of Tenbury. On some of the hills, about one mile and a half south-east of that town, are heaps of this gravel charged with some of the

[1] Townsend, in his Vindication of Moses as an historian, gives similar instances of local drift in the valleys of the Frome and the Avon. Where these streams are separate, the drift belongs to the peculiar region through which the rivers flow; but after the junction of the two streams, the drift is of a mixed character.

above varieties of rock, and also with a number of fragments of coal measure grits, mountain limestone, and basalt. As all these materials occur in situ in the Clee Hills, distant only a few miles north-west from the spot, we have in this case additional evidence, that all the ancient submarine currents of this district followed the same direction.

Let us now follow the Wye from its source into the plain of Hereford, and we shall there find precisely the same phenomena as in the valley of the Teme,—the transported matter changing its contents with every successive zone of rock. In the upper or north-western region of the river, about Rhayder, the fragments have been entirely derived from the slates and quartzose conglomerates of the Cambrian System. Similar materials with broken schists of the district are spread over the arid tract between Dolfan and the Builth Hills, but having passed the volcanic chain of Builth, we meet with vast numbers of large porphyritic and greenstone bowlders, altered quartzose strata, &c. piled up in the hollows or upon the slopes of the outer zone of Silurian rocks. These coarse fragments, are one and all referrible to the group of rocks lying to the north-west, and which mantle round the volcanized region extending from Builth to Llandrindod and Llandegley; and they are often lodged at heights of many hundred feet above the bed of the Wye. They are not arranged in terraces, as if produced by any possible fluviatile action, but are piled up in confused and irregular heaps in the mountain combs.

The reader should be here again reminded, that this coarse drift is by no means confined to the *sides* of the transverse chasms through which the Teme, the Wye, and other streams escape into the low country, although such fissures appear to have afforded the detritus a ready egress, it being usually propelled further to the south-east in the prolongation of these openings than elsewhere. On the contrary, this coarse drift is strewed at intervals over the sloping dry combs and *high grounds*; particularly where they lie to the south-east of any tract which has been the theatre of volcanic eruption or violent elevation of the strata. For example; large bowlders of trap and hard quartzose rocks occur on various hills east of Llandrindod and Builth, (Pl. 33. f. 7.) and the same may be seen on the south-eastern slopes of the Hergest ridge, near Kington, or south-eastern talus descending from the volcanic group of Old Radnor. (Pl. 33. f. 4.) The vast accumulation of coarse detritus, already alluded to, as impoverishing a wide tract between Kington and the Hay, was also drifted from the same centre of action.

In descending the gorge of the Wye to the south-east, we find the materials of all the rocks derived from the volcanic district of Builth, rapidly diminishing in size, and lodged in great mounds against the escarpments of the Old Red Sandstone. As we advance to the south-east, these materials become smaller, and at length in the environs of Hereford they appear only as fine gravel and silt. Again from Hereford to the mouth of the Wye, the bowlders change with the lithological characters of the districts traversed, and are referrible to the grits and conglomerates of the coal measures and Old Red Sandstone.

In the central parts of Herefordshire, the effects of powerful denudation are also apparent, though few or no remains of the abraded strata are exhibited. Such action is clearly displayed in the form of the two Pyons. These conical hills, seen at great distances throughout the county, consist in their lower part of the argillaceous marls of the Old Red Sandstone. The soft materials of which these strata are composed, and by the former extension of which, these two conical hills were once doubtlessly connected, have been entirely swept away, and the present form of the hills has alone been preserved by caps of semi-conglomerate cornstone. Thus to the perishable nature of the strata must be attributed the usual absence of gravel in the centre of Herefordshire. Even upon reaching the chain of the Abberley and Malvern Hills, where a lofty ridge of syenite and greenstone has risen through the Silurian rocks and Old Red Sandstone, we find little or no coarse detritus upon the western side of the ridge, except in two hollows immediately beneath the hills, in which are heaps of angular and disintegrated syenite. One of these hollows occurs near Colwell Green, and another near the Eastnor Obelisk. No gravel, however, properly so called, occurs on the western flank of the Malvern Hills, except a small patch near Clencher's Mill, which has been accumulated in a trough between the Silurian ridges of Malvern and Ledbury, from both of which the materials have been derived. On the east side of the Malverns, on the contrary, accumulations of the wreck of the syenite and Silurian rocks flank the gravel of the valley of the Severn or the northern drift, the consideration of which occupies the next chapter.

The absence of all fine or coarse detritus in the valley of elevation of Woolhope has before been pointed out, the only remains of the broken materials which have been swept out from the interior of that remarkable valley, being partially heaped up at the mouth of the principal gorge by which it is drained. In such a case we should expect to find the debris where it is, namely, lodged only at those points of its margin, which, having been broken through, permitted the disintegrated materials to escape by transverse apertures from the centre of elevation. Such examples offer, indeed, the most convincing proof of purely *local* drift.

From Herefordshire or the great water-shed of South Salop and Radnor, let us pass into the drainage of the Usk, and see if it offers analogous evidence. The valley of the Wye is separated from that of the Usk by the lofty chain of Old Red Sandstone, called the Black Mountain, the highest points of which are about 2300 feet above the sea. Whether we cross this dividing ridge in the neighbourhood of the Hay where it is high, by the lateral valleys in which the minor streams flow from north-west to south-east, or by the Monmouth Cap, where it is comparatively low, we meet with finely levigated red silt only, or gravel both coarse and fine, derived from the cornstone or other members of the surrounding Old Red Sandstone[1]. When we descend into the

[1] The embayed flats south of Whitfield and north of Monmouth Cap, are good examples of the fertile soil produced by the breaking up and disintegration of these materials.

valley of the Usk, the narrow transverse valleys in which the minor streams flow from the crest of Old Red Sandstone, as well as the south-eastern face of the mountains, are loaded with bowlders of that rock alone. In the broad and deep valley of the Usk itself, from the west of Crickhowell to Abergavenny, is much coarse gravel, lodged sometimes several hundred feet above the present bed of the river. A part of this gravel has also been transported from the mountains of Old Red Sandstone (on the north-west), but the greater portion has, doubtlessly, been derived from the margin of the contiguous coal basin of South Wales, which from Crickhowell to Newport, constitutes the opposite side of this deep depression.

The enormous accumulations in the vale of the Usk, between Crickhowell and Abergavenny, have been previously cited, as the necessary results of the powerful dislocations and denudations to which this valley owes its origin; and the amount of the wreck has been satisfactorily explained by showing, that the insulated and lofty limestone peak of Pen Cerrig-calch, now distant five miles from the edge of the coal-field, has been separated from the main mass of the formation by the scooping out of the intervening valley to the depth of 1200 or 1500 feet. (See p. 163.)

The Usk, from its source to its mouth, winds round the escarpment of this coal-field, and hence, in the valley watered by it, we find an intermixture of detritus produced by currents, which have flowed from *different centres of elevation.* A great number of the fragments of the Old Red Sandstone have been drifted from north-west to south-east, owing to the ancient elevation of the region; but the broken materials of the coal-field have been carried from the south, south-east, and south-west, towards the north, in consequence of the east and west movement before described (p. 406), *each drift proceeding from independent points of disturbance.* These drifts have been arrested upon certain promontories only; thus, for example, although they are in great force around the town of Abergavenny, obscuring the lower sides of the surrounding mountains, yet the lower limits of the Little Skyridd, reaching to Llangattock, are free from such coarse detritus, presenting slopes of deep red loam, which terminate in the sandy and gravelly bed of the Usk. In descending this valley to the town of Usk, the river flows through a large, elliptically shaped mass of Silurian rocks, already described as rising in the form of an irregular valley of elevation. (p. 441.) The western face of this insulated mass of rocks, which approaches within a few miles of the external lip of the coal basin, has been covered by a prodigious quantity of bowlders and coarse gravel of the coal-field, the hard white grits predominating; the red matrix and chief mass having been derived from the surrounding Old Red Sandstone. The bowlders of the coal measures can be traced up to the mouths of large transverse rents in the edge of the adjoining coal basin (Pontypool, &c.); and the chasms prove what vast masses of solid rock must have been abstracted from them. These materials were no doubt poured down into their present situations during those periods of elevation when the adjoining carboniferous strata were thrown up and fractured.

It must be observed, that these bowlders are *not* strewed in the direction of the existing water courses, but have been propelled to the east and north-east, thus meeting the ancient or north-western drift[1]. It has also been shown, (p. 441,) that the centre of the uplifted mass of Silurian rocks near Usk, is as free from gravel or other detritus as the valley of elevation of Woolhope, all the broken materials having been shot off from the centre to the flanks. But although the interior of the Silurian tract of Usk has been shielded in its southern part, from the sterilizing effects of an overflow of carboniferous detritus, the northern portion, including the hills of Lancayo, Trostrey, and Clytha, as well as a large tract of Old Red Sandstone, extending by Penrose to Llantillio, exhibit some large bowlders with much small gravel of the coal-fields. This is brought forward as an addition to the other proofs which have been adduced, to show that the periods of elevation of the Silurian and carboniferous rocks were independent and distinct; and it by no means affects the inference, that all such materials were accumulated under the sea. In the tracts further removed from any coal-field, as at Ragland, are no large bowlders, but small pebbles only of millstone grit, mixed up with vast quantities of fragments of the Old Red Sandstone. In some parts of the district between Clytha and Llantillio, lying to the south and south-east of the Holy Mountain, which is composed of Old Red Sandstone, the bowlders consist exclusively of the hard beds of that formation, and are of so great a size as to be split up for building purposes, in the absence of regular quarries. In following these bowlders from Llantillio southward, they become smaller as we recede from the flanks of the mountains, and at Clytha all the gravel is round and finely comminuted, of great thickness, and it alternates with layers of sand. Not a vestige of trap or of any rock foreign to the drainage of the district, is to be found in these deposits. On descending the Usk from the town to the river's mouth, the coarse detritus also gradually disappears, giving way to fine sand and silt, through which the stream winds to the estuary of the Severn.

Another striking example of a mass of coarse drift, thrown off by elevation, is displayed on the south-eastern talus of the Brecon anticlinal, and all the phenomena agree with those previously described. A sharp and highly dislocated ridge of Upper Silurian Rocks has been elevated on a line from north-east to south-west, and the country on the north-west being higher than that to the south-east, the drift has all been carried in the latter direction. The great transverse faults by which this ridge has been fissured, have necessarily become the beds of the existing water courses of the two

[1] This ancient drift is very distinct from the modern detritus carried down from the gorge of Pontypool, and described by Dr. Buckland (Geol. Trans., vol. v. Old Series, p. 531.) as forming a naked strand of pebbles beneath the escarpment of mountain limestone. The dissimilarity between the river deposits and the ancient drift will be hereafter pointed out in the case of the river Sowdde. The reader will bear in mind, that all the transported matter described by Dr. Buckland as *diluvium*, and which he considered to have been swept over pre-existing land, constitutes in my view *submarine* detritus of various dates, while his *post diluvium* is simply a subaerial deposit.

flattened shingle and fine gravel, derived from the adjacent Cambrian and Silurian rocks. At Caermarthen the river becomes already a navigable estuary, the channel no doubt having been excavated by the river itself through mud and silt of its own deposition. On the sides of this modern delta there are, however, hillocks which contain indications of separate ancient operations. One of these mounds, called Goylan-goch, on the left bank of the river, exposes a vertical section of 30 to 40 feet. The upper half is made up of coarse gravel of a brown yellow colour, containing many bowlders of Old Red Sandstone, millstone grit, &c. This mass is neatly separated from an underlying accumulation of finely laminated black shingle and coarse grey Cambrian and Silurian gravel, with here and there dividing laminæ of fine, light-coloured sand. The arrangement in this hillock, therefore, presents two periods of aqueous agency entirely unconnected; one anterior to, the other following the elevation of the adjoining coal-field. Such results might be expected from the elevation of the Silurian rocks and lower portion of the Old Red Sandstone, which, it has been shown, gave rise to the most ancient state of the vale of the Towy, whilst the subsequent upheaval of the coal-field produced the detritus which covers the Silurian drift.

The soft and destructible nature of the mountains, and the absence of decided ridges of elevation in the north-western parts of Caermarthenshire, account for the paucity of large bowlders proceeding from that quarter, which under other circumstances might have found their way into the vale of the Towy.

*Superficial detritus of Pembrokeshire.*—The detritus which appears on the surface of most parts of Pembrokeshire, is of a simple character, and, as in other parts of South Wales, is of *local origin.* It consists of fragments of greenstone, porphyry, Cambrian grits, &c., all of which can be traced to the various mountains forming the crest of the county. In some parts, this detritus is exceedingly coarse, as in the tract west of Nolton Haven, where the blocks of trap are numerous and vary in breadth from less than a foot to several yards. In other tracts, as north of Haverfordwest, we meet with finely comminuted gravel; but this is rare. On the whole, though much denuded in some districts, Pembrokeshire is exempt from any traces of those sediments, which in other parts of South Wales may be referred to lacustrine and fluvio-lacustrine accumulation; a fact which harmonizes remarkably with its physical features. The region is truly one without any freshwater streams of sufficient length and width to be worthy of the name of rivers; and there are no natural depressions of any extent in which surface accumulations could be received. Such, indeed, must be the case in a tract, not only flanked on three sides by the sea, but also fissured by the great chasm of Milford Haven and its tributary creeks, through which the tide now flows by devious branches to the very heart of the county. It is highly probable that a large portion of the coarse detritus, remnants of which still partly encumber the surface of this tract, has been swept down and carried out to sea through these deep channels. We are led to form this opinion, because the lower and southern end of the county consists of undulating hills of slight elevation,

singularly void of drifted matter. The lines of most powerful dislocation are, however, often obscured by heaps of rubbish, already alluded to in describing the remarkable elbow of Silurian rocks and Old Red Sandstone near Cyffic[1].

The facts recorded of ancient drifts, in positions not within the range of existing drainage, must have great weight in leading us to conclude that the coarse materials thus strewed over the surface cannot have been accumulated by fluviatile action, but by bodies of water which had certain directions given to them, and which have fixed relations to the lines upon which the strata have been elevated. The Teme and the Wye, with their tributaries, flow in the same direction with the marine drift, and hence the higher sides of their valleys are naturally loaded with detritus derived from the slopes of the elevated north-western ridges. But wherever the rivers quit the main course of this ancient drift, we no longer find that they have upon their banks similar coarse materials.

The Severn affords an excellent illustration of this rule. That river, rising in the eastern slopes of Plinlimmon, first follows a devious course to the north-east, and passes through Montgomeryshire in a longitudinal valley *parallel* to the strike of the chain. Beyond Welch Pool it is increased by the united waters of the Ffyrnwy and the Tannat, and then glides from the Welsh territory into the plain of Shrewsbury. Now, if existing fluviatile action had been concerned in transporting the coarse drift and bowlders, some portion of the materials would accompany the Severn in its course to the north; but not so: all such materials are left behind, in the tract whence that river escapes, and without reference to any line of existing drainage, are strewed over *hill and dale* in a south-easterly direction, having thus obeyed the great movement impressed upon them by the elevation of the adjacent chains.

[1] Besides the detritus above described, Pembrokeshire contains a small singular deposit, to which my attention was directed by the Earl of Cawdor, namely, an accumulation of pipe-clay, chiefly white, but sometimes striped red, or mottled like Castile soap. It alternates, and is in part mixed up with gravel, composed principally of pebbles of white quartz. This mass occurs about three miles west of Stackpole Court, and covers about five or six acres of the carboniferous limestone of that promontory. It has been cut into to a depth of 45 feet, 35 of which have, in some parts, proved to be of pure pipe-clay without a pebble. In other parts the clay becomes nearly black towards the bottom. It makes excellent earthenware, especially when mixed with about one third of the coarser clay. The whitest quartz pebbles, being selected and sifted, are ground into powder, which being united with the clay forms excellent fire bricks. As the tract of Stackpole, the southernmost promontory of Pembroke, is entirely free from other detritus, it seems difficult to account satisfactorily for the origin of this patch of clay and gravel. On the whole, however, it so strongly reminded me of the older tertiary deposits on the coasts of Hampshire and Dorsetshire (particularly in the composition and aspect of the pipe-clay), that when on the spot I could hardly resist the persuasion that this accumulation might be a relic of the same period*. The quartz pebbles, indeed, were evidently derived from the adjacent conglomerates of Freshwater West, on the north; and, therefore, to whatever epoch we assign it, this matter has been drifted in the same direction as all the other detritus of Pembrokeshire.

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* M. Elie de Beaumont will probably remark that this deposit, like those of Hants and Dorset, is on a line of fissure proceeding from east to west.

In concluding this chapter, I may state, that after a patient examination of the older drift and its purely local character throughout this region, its production is best explained by reference to those movements by which the solid strata were successively upheaved from below the sea; on which occasions, the beds being much shattered, all loose fragments were thrown off upon their slopes. I may, perhaps, venture further, and assert that the following positions have been established.

1. That the drifts being of local origin, the agency must also have been local.

2. That the dry combs and depressions in which no streams flow, but in which large masses of drift are lodged, must have been excavated or modelled by a body of water which once filled them; and as that water could not have been derived from the drainage of the country, it consequently must have been produced by the combs being below the level of the then existing seas, and having a direct communication with them.

3. That the action of this water, affected either by tides or periodical freshes, produced in part the detritus, wearing it down into pebbles and sand.

4. That the volcanic outbursts and local disturbances, of which so many proofs have been adduced, caused, from time to time, tumultuous currents, which accumulated the irregular heaps or hillocks of coarse drift; the same disturbances probably producing permanent changes in the relative level of sea and land.

5. That these operations gradually changed the hydrographical characters of the districts, and eventually converted the estuaries into lakes and rivers. The processes by which these bodies of water were filled up or reduced to their present size will be considered in the sequel.

Whether all these deductions be admitted or not, it must be acknowledged, that as Siluria is exempted from all the far transported detritus so prevalent in the surrounding parts of Great Britain, the region cannot have been visited by a great deluge flowing from other countries after its features had been determined and its present valleys excavated. In this respect, indeed, it bears the same relation to the British Isles as Auvergne does to the whole of France; the surfaces of both these isolated tracts being covered by local detritus only, though environed by countries loaded with foreign debris[1].

[1] See Lyell and Murchison on the Excavation of Valleys in Central France, Edin. New Phil. Journal, vol. vii. p. 15. I hope not to be charged with egotism when I state, that this memoir, in conjunction with the writings of Mr. Poulett Scrope, was among the first which fairly brought the diluvial question to issue in this country, and gave rise to those discussions which led to the refutation of the belief in a general terrestrial deluge, which had affected simultaneously all the surface of the globe.

# CHAPTER XXXVIII.

## THE NORTHERN DRIFT.

1. *On a Northern Drift containing granite bowlders and sea shells of existing species, which covers large parts of Lancashire, Cheshire, Shropshire, Staffordshire and Worcestershire; prefaced by a sketch of the probable condition of the surface before and during its deposit, comprising a short account of the local detritus which the northern drift covers and with which it is partially intermixed.*

QUITTING the Silurian region, which is covered with local detritus only, and passing its northern or eastern limits, we enter districts where a large portion of the accumulations are associated with others which have been transported from Cumberland, and probably even from Scotland.

The former hydrographical condition of this tract cannot, however, be considered without assuming the following positions, which are established in the sequel. 1st. That the granitic and other detritus derived from the north, constitutes, wherever it is found, the uppermost part of the drifted matter, and contains sea shells of existing species.

2nd. That this granitic and shelly detritus never enters into the region occupied by the Silurian drift, but sweeping round its northern face, extends in an elongated deltoid form along its eastern flank, either covering or mixing with the local drifts with which it comes into contact.

By the term northern drift is, therefore, simply meant an accumulation of materials, the *chief* mass of which had a northern origin; for here, as in the region of Siluria, there are also evidences of local drifts. Now, though we may be unable, on all occasions, rigorously to define the demarcation between the local drifts and the northern drift, yet from structure and composition there can be no doubt that all these accumulations were formed by long-continued aqueous action; and that the northern granitic detritus with marine shells of existing species indicate the *last* of such operations. Evidence will hereafter be adduced to show, that while this northern drift was accumulating, that is, during the latest period at which the region was submarine, not only was Siluria above the waters on the west, but also a large portion of England on the east. The

latter point is established, by the remains of land and fluviatile animals accompanying the detritus of eastern rocks. These observations will afford the reader a general view of the subject; and while perusing the following details he must bear in mind that a large portion of the centre of the map was under water after the other parts had been raised above it. This recently submerged tract includes the eastern parts of Lancashire, nearly all Cheshire, the north of Shropshire, and large portions of Staffordshire, Worcestershire and Gloucestershire, being the region coloured as New Red Sandstone. In proving that these districts were under the sea, while Siluria and Wales on the one side, and a portion of England on the other, were above it, we assume that the submarine tract had towards the north the form of a great bay, which tapering towards the south, terminated in a strait. It is specially to the central and southern parts of this space, that I now proceed to call attention[1].

*Local or underlying Detritus of the region overspread by the Northern Drift.*

The subsoil of two thirds of the tract in question consists of rocks of the New Red System. The oldest strata (with the exceptions near Dudley and Tortworth) belong to the carboniferous series, which, when heaved up through the New Red Sandstone, occasioned, at various points, a vast destruction of solid matter. (See illustrations in chapters 36 and 37.)

The consideration of this local detritus will be brief, for its composition and structure lead us to suppose, that it must have been accumulated beneath the sea or in estuaries, in the same manner as the coal measure detritus described in the last chapter, and possibly at the same period. The surfaces of the Salopian and Staffordshire coal-fields present, indeed, very generally, the same phenomena; vast masses of the New Red Sandstone with which they were once covered having been broken up and distributed in irregular mounds of fine sand and gravel. Sometimes the fine sand predominates; but more often is intermixed with shingle-like gravel, both coarse and fine, derived from the New Red Sandstone and adjacent rocks. In certain parts, rounded quartz pebbles alone prevail; in others, vast masses of clay inosculate with beds of sand and gravel. Everywhere, however, the deposits clearly prove, that their materials were derived from the neighbourhood of the localities where they are now accumulated. Taking, for example, the tract surrounding Dudley, and examining into the composition of the oldest or local detritus, we immediately perceive, that it must have been principally produced by the upheaval of the carboniferous strata through the overlying red sandstone; for it contains great quantities of the latter in a triturated state, also rounded pebbles of quartz, derived from the disintegration of the conglome-

[1] The present relative levels of land are so prodigiously changed since the early condition of the region, that some of the tracts containing recent shells on the surface are upwards of 1700 feet above the sea, while adjacent Silurian tracts elevated at much earlier periods, now lie at very low levels.

rates; and the only other materials are referrible to the adjacent Silurian and trap rocks. Although these accumulations have often a very variable aspect, I confess I am unable to draw any distinctions in their age. In some places, the sands appear to occupy the lowest position; in others vast masses of clay, 100 or more feet thick, the decomposed shale of the coal-fields, mixed up with broken coal, grit, &c., underlie the sand; and again the sand, clay and gravel are dovetailed into each other. Hence we must conclude, that they all resulted from long-continued, submarine currents, which acted in different directions and were influenced by the various movements of elevation and disturbance to which, we know, the district was subjected. (See chapters 36 and 37.) A fine section of this detritus of the Dudley field, has recently been laid open about five miles from Birmingham in cutting the grand junction rail-road. The upper part consists, of from 25 to 30 feet, of foxy-coloured sand with rounded quartz pebbles, varying in bulk from 4 or 5 inches, to the size of a wren's egg. This sand rests, in one part, irregularly upon a mass of 60 or 70 feet of bluish clay, in which small pebbles occur at intervals, and more frequently angular fragments of the coal-field; also occasionally concretions of iron-stone with small pieces of coal[1]. If the north-eastern side only of the deep cutting were examined, the clay or lower portion of the deposit might be conceived to indicate an earlier period of denudation; but on further research, sand, apparently the same with that which lies above the clay, is found to rise in wedge-shaped and irregular masses through it, thus compelling us to assign the whole to one epoch. In this detritus, I could trace no signs of the granitic or northern drift, for though the northern bowlders are strewed plentifully *over the surface* of the eastern and northern faces of this field, they are not intermixed with this local detritus. The quantity of small rounded pebbles of quartz rock around certain parts of the tract is very great, particularly near Bar, and thence towards Lichfield. Still larger quantities of the same pebbles are piled up on the western slopes of the Clent and Higher Lickey Hills. It must not be imagined that these quartz pebbles were rounded by the action of the water which strewed this detritus over the bottom of the sea. They are, in fact, evidences of the action of the more ancient bodies of water, which formed the conglomerate of the New Red Sandstone, &c., their present distribution having been simply due to the disintegration of those rocks, and the disturbances before alluded to[2].

[1] In many parts of the adjacent districts drifted fragments of coal are found in the superficial detritus, and these have occasionally led idle speculators to dream of coal-fields *in situ*. Such coaly detritus occurs near Bobbington, between Dudley and Bridgenorth, and also at Powick and other places near Worcester. At the former place it covers the New Red Sandstone, at the latter the "Keuper" marl of the same system.

[2] In his memoir on the quartz rock of the Lickey Hill (Geol. Trans., vol. v. Old Series.), Dr. Buckland has clearly explained, that these pebbles were rounded by ancient and not by diluvial action. He supposes, that many of these quartz pebbles of the central counties, were originally derived from the little ridge of quartz rock of the Lower Lickey Hills (which I have shown to be altered Caradoc sandstone), indicating, at the same time, that most of them had been first formed into conglomerates of the New Red Sandstone, and afterwards distributed by diluvial agency. If the present configuration of the country be considered, it would be im-

Again, around the field of Coal Brook Dale, there is distinct evidence of much local detritus, derived from the breaking up of the red sandstone and the protrusion of coal measures, Silurian rocks, trap, &c.; and the local detritus is overlaid by the drift containing northern bowlders[1]. Excellent examples of this superposition may be seen near Buildwas and the Iron Bridge, where mounds of regenerated red sandstone, the residue of the rocks shattered during the rise of the coal-fields, are wholly exempted from foreign detritus, though the latter, containing many varieties of northern granite, is found on the surface, both surrounding and partially covering the coal-field.

Similar phenomena, though of rather a more complicated character, are observable on the banks of the Severn, near Shrewsbury, as expressed in the accompanying woodcut.

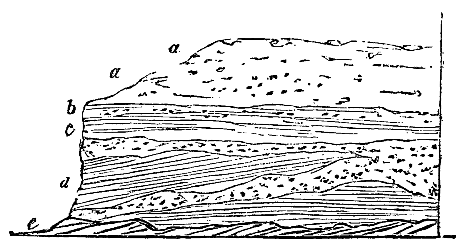
*Section on the right bank of the Severn at Preston Hall, 4 miles south-west of Shrewsbury.*

107.

Northern Drift?
- *a.* Soil of heavy clay and loam containing a few bowlders of northern granite, fragments of Silurian and Cambrian rocks, and small pieces of the carboniferous strata, inosculating with sandy loam and sand.
- *b.* Reddish foxy sand, in fine layers alternating with laminæ of brown sandy clay, a few pebbles, &c.

Local.
- *c.* Irregular alternations of coarse gravel and finely laminated sand. The former contains shingley, flattish, waterworn fragments of all the surrounding rocks, the sand being of light red colours. No granite in this mass.

*d.* Regenerated red sandstone.
*e.* New Red Sandstone.




Sections varying in detail, but presenting the same general arrangement, are visible at Shelton Rough and other places on the banks of the Severn, near Shrewsbury. At the base they consist of soft deep red sandstone without any foreign pebbles, the mere disintegration of the red rock, which is seen beneath *in situ*. This bed is covered by mixed detritus of foxy-coloured gravel, made up of the rocks above mentioned, with chert and grit of the coal measures, and being of a dingy grey tint, it is strongly contrasted to the red colour of the underlying mass. A speculator might endeavour to prove, that these deposits, being of different colours and composition, are referrible to separate epochs of drift. He might argue (and with plausibility), that after the great banks or shoals of red sand, which generally occupy the lowest position, had been elevated to a certain extent, matter of different composition was drifted on them, the sand banks themselves being modelled and rounded off by the action of the retreating sea. But I have seen too many cases in which that order is reversed, and in which red sand re-occurs, overlying grey detritus of coal grits and older adjacent rocks, to admit such a speculation. All we can safely affirm, is, that the different sections vary very much in their composition; though they all have the aspect of having been

practicable to refer the great heaps of these pebbles in the eastern slopes of the Clent or Higher Lickey to the little ridge of Lower Lickey. The various sites of the same quartz rock, near the Wrekin, Caradoc, &c., were probably the sources of these great masses.

[1] Mr. Prestwich has also noticed this arrangement, Geological Proceedings, vol. ii. p. 404.

formed by *long-continued submarine action;* that the materials occupying their *lowest* stages can invariably be traced to their parent rocks within very moderate distances; and lastly, that the purely local detritus is generally covered by clay, sand, and gravel, with bowlders of the northern drift, though the latter are sometimes *intermixed* with the underlying accumulations of local origin. Similar sections may be seen on the surface of the lias tract between Prees and Whitchurch, where much local detritus is covered by clay and loam containing granite bowlders, the latter lying both on and near the surface, and at small depths in the local gravel. Many more examples might be given, but enough has been stated to show, that the great mass of this local drift underlies the northern. In Worcestershire and in Gloucestershire, the same distinctions can be drawn between local and far transported debris. Large portions of the eastern side of the vales of Gloucester and Worcester are strewed with accumulations of purely local character, derived from the adjacent oolite escarpment, or from the outliers of that system. Near Cheltenham, Evesham and other places, this fine local drift fills depressions in the lias, or is troughed in gullies on the lower slopes of the Cotteswold Hills[1]. Half of the town of Cheltenham is built on such materials, in parts comminuted to a fine sand in which I never observed the fragment of a distant rock. The northern drift is of very different character, and sweeping down the central part of the same valley, it caps, north of Evesham, hills of 300 or 400 feet in height. Below Worcester it composes lower hillocks, derived both from the Oolite on the east and Silurian rocks on the west, *mixed up* with the finely laminated fragments of northern origin.

After this description the reader will perceive, that it is not always practicable to separate the more ancient or local drift from the more recent or northern. Nor ought we to find such separations; for as the materials of the former lined the bottom of the sea when the latter was deposited, there must have been a partial intermixture. Nay, more, if (as I believe) Siluria and the larger part of Wales were dry land, while the country now covered with the northern drift was submerged, the rivers flowing from the former region must have transported fragments of Silurian and other rocks into the same sea in which the granite detritus of the north was accumulated, and in which lived the shells found associated with it. Examples of this intermixture occur specially along or near the *borders* of ancient Siluria[2].

[1] I do not mean to assert that the local sandy detritus, near Cheltenham and Evesham, is of the same age as the local drifts of Salop which underlie the northern drift. Some of it may be even younger than the northern drift. Neither Mr. Strickland nor myself have ever detected any organic remains in these local, sandy deposits, which have no distinct relations to the general drift. See "Outlines of the Geology of Cheltenham and neighbourhood." R. I. Murchison.

[2] Much caution is required in distinguishing local from far transported detritus; for what may appear to belong to the latter can often be strictly referred to the former. Thus, for example, the disintegration of the calcareous conglomerates of the New Red System on the left bank of the Severn, besides pebbles of quartz rock, afford fragments and fossils of the carboniferous limestone; and as no portion of that rock is *in situ*, these fragments might be supposed to have been drifted from a great distance, when the alluvial matter was deposited.

*Northern Drift, containing Granite Bowlders and Sea Shells of existing species.*

The region thus partially occupied by local detritus, derived from *various centres*, is *overspread* by a great drift from the north, which, as has been already stated, covers large tracts of Lancashire, Cheshire, Shropshire, Staffordshire and Worcestershire. The country from which this drift proceeded is clearly shown by its contents, for none of the varieties of granite and other rocks which it contains, occur in Wales or the adjacent parts of England, but they are all well known to exist in Cumberland and Scotland. This granitic detritus is further proved to have issued from the north, not only by its greater volume in that direction, but also by the blocks diminishing gradually in size as they are traced from north to south. On or near the coast of Lancashire (as at Preston)[1] the thickness of the drift is 150 feet and more, consisting, in some parts, of deep masses of clay, in others of sand and fine gravel, in all of which large bowlders of granite are mixed up with some local detritus and sea shells of existing species. The drift thus characterized (and traceable almost every where by its granite bowlders on or near the surface) covers a very large portion of Cheshire and the adjacent tracts of Staffordshire and Shropshire; thus ranging over nearly the whole region coloured as New Red Sandstone with patches of coal measures. On the east it has no well-defined limit that I have *yet* observed, until it reaches the vale of Worcester, where it occurs in the form of a delta, included between the Silurian hills on the one side and the Cotteswolds on the other; both of those hilly ranges being entirely free from it. The greater part of its western flank is clearly defined. Advancing from the low country, south of Liverpool, it has swept across Flintshire, but has been arrested on the edge of the North Welsh mountains[2]. On Moel Tryfan it occurs at nearly 1750 feet above the sea. The chain of mountain limestone and millstone grit, constituting the edge of the high lands of Denbighshire, seems to have been the ancient shore of this drift[3]. Near Wrexham it forms masses of vast thickness, con-

But this is not the case, for their *transport* took place during the accumulation of the deposits in which they were imbedded, previously to the action of the waters, which formed the superficial drift and only loosened them from their parent bed and moved them a short distance.

[1] I communicated some of my views concerning this northern drift, as seen at Preston and other places, to the first meeting of the British Association, September 1831, and I inferred, from the phenomena which I had then noticed, the recent elevation of large portions of the island. See Lyell's Principles of Geology, vol. i. p. 269, and Map. The area over which I have examined the phenomena has since been very widely extended.

[2] Mr. Trimmer first called attention to the sea shells and coarse granitic gravel on Moel Tryfan, 1692 feet above the sea.

[3] Mr. Bowman, of Gresford near Wrexham, has favoured me with some valuable details concerning the structure of the drifted materials in that neighbourhood. He has detected as many as 13 different varieties of granite, mixed with other rocks of northern origin, and a great proportion of fragments derived from the adjacent grits and limestones and slaty rocks. Mr. Bowman read an interesting memoir on the Cefn Caves to the British Association at Bristol, 1836, which has not yet been printed, in which he treats incidentally of this

taining a variety of granite pebbles mixed up with a large proportion of the adjacent Welsh rocks, including the coal measures; and the same distribution of materials prevails to Oswestry, where the southern course of the drift seems to have been checked by promontories of the carboniferous rocks.

Let the reader bear in mind, that from Oswestry to Shrewsbury there are no continuous ridges, ranging from west to east, which could oppose the southward course of this drift. On the contrary, the ridges of Silurian rock trending from the south-west, expose their north-eastern extremities, leaving between them a succession of longitudinal valleys which are open to the tract which is strewed over with the granite bowlders. The most striking of these valleys is that of the Severn, which river, issuing from the Welsh and Silurian regions in a northern direction, enters the country covered by the northern drift, and winding through it to the Iron Bridge, then traverses a gorge at the north-eastern extremity of Wenlock Edge. (See Map.) Now, if the present relative positions of the Silurian and northern drifts had existed during their accumulation, or if Siluria had not been then at a higher level than the submerged district, the northern drift must have been propelled far into the low depression from which the Severn issues into the plain of Shrewsbury. But though this drift lies on contiguous heights, several hundred feet above the Welsh Pool valley, not a pebble of it can be traced southwards into the low grounds beyond the Breidden Hills, all the detritus there being exclusively of Welsh origin. Again, the longitudinal[1] valleys on the sides of the Long Mountain, between the Longmynd and the Caradoc, or between the latter and the Wenlock Edge, all exhibit the same phenomena. Their northern and north-eastern extremities being low, are consequently *open* to this line of drift, yet they are wholly exempted from any portion of its debris, which is lodged in such great quantities upon the opposite slopes of the Wrekin, Haughmond Hill, &c. The fair inference, therefore, is, that great changes have taken place in the relative levels, and that the Silurian region was above, while the tract occupied by the northern drift lay beneath the sea. In other words, while the country about Shrewsbury was sea, the Severn of that epoch must have terminated at the Breidden Hills, by emptying itself into a bay, in which the northern drift was accumulating.

This hypothesis is further sustained, by tracing the present line of the Severn to the south, after it has escaped from the gorge of Bridgenorth. Throughout this portion of its course, the river flows in the *same direction* as the great northern drift; and thus

gravel around Wrexham; stating, that from its structure, composition and method of deposit, it must have been formed by very long-continued subaqueous action, and is wholly unlike the result of a transient inundation. His views are, therefore, quite in unison with my own.

[1] By *longitudinal* valleys is meant those which range parallel to the ridges or general strike of the mountains. The country is *now* drained by rivers flowing through valleys or gorges *transverse* to these ridges. (See Map.) Example the Severn at Coal Brook Dale; the Teme at Downton, Ludlow, and Knightwick Bridge; the Lugg at Aymestry; the Wye between Ross and Chepstow, &c.

the elbow made by the latter from Oswestry to Bridgenorth can be explained satisfactorily by inferring, that the Silurian region constituted an ancient line of shore, during the period when the whole of the present valley of the Severn, from the Breiddens to the mouth of the river, was submarine.

We shall hereafter afford independent proofs of the existence of dry land on each side of the narrowest portion of the region then submerged, by showing that fluviatile and land remains were washed into it from both sides and mixed up in shore detritus. In the mean time, I would simply remark, that as the northern detritus with sea shells, where it advances to the south, is never found on the ranges which flank the present estuary of the Severn, but is strictly confined to the level country; so the form of the tract strongly supports the belief in the existence of a great channel of the sea, extending southwards through Worcester and Gloucester; the eastern and western shores of which were the Cotteswold and Malvern Hills. The former chain presents sloping escarpments to the valley of the Severn, with salient and re-entering angles, precisely like the headlands of a shore, formed by the action of a sea acting upon the soft and hard materials. At the base of these oolitic hills are masses of local detritus, in the form of sand and shingle as before described. On the opposite side the sharp ridge of the Malverns stands out like a mural buttress on the flank of the Silurian region, reminding the traveller of rocks of similar form and composition on the sides of straits[1]. How far over the kingdom the eastern limb of the northern drift may have extended, and whether even the whole drift under consideration, is not a portion of that which covers such large tracts in the east and south-east of England, remains to be determined. There is, however, every reason to believe, that in the tracts adjacent to the eastern limits of the annexed map, the north and south valleys, such as those of the Evenlode and Cherwell, may have been under the sea during the same period. The excellent and clear description of the physical features of these tracts given by Dr. Buckland (Geol. Trans., Old Series, vol. v. p. 516 *et seq.*), and his account of the transport of the quartz pebbles derived from the Lickey Hills and the conglomerates of the New Red Sandstone of the central counties, mixed with fragments of *northern* origin, seem to me to indicate, not as is inferred in that paper, the rush of diluvial waters over pre-existing land, but that the tracts, so covered, were under the sea during the period of the northern drift, the Cotteswold and other ridges, as before stated, being *then* above them. Judging, however, from the vast mass of gravel, occasionally charged with modern marine shells, which covers such large portions of the eastern counties, the area which was then submerged must have been very great, and consequently the amount of existing dry land inconsiderable.

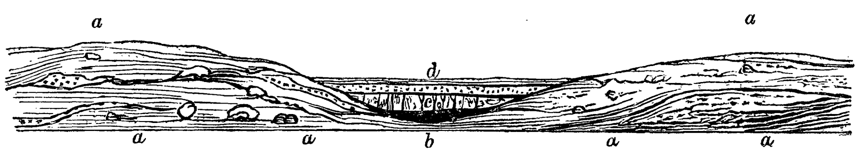
I have said that the drift under consideration is specially distinguished from all local detritus by containing fragments of northern rocks, many of which are of vast size, and

[1] If the valley of the Severn were under the sea, the Malvern ridge would strikingly call to mind the rock of Gibraltar.

sea shells of existing species; and that by these features, both the direction in which the chief detritus was carried, and the epoch of its deposit are clearly established. It would fatigue my readers, and convey no additional knowledge, to describe all the situations where such phenomena have been observed. So numerous, indeed, are the localities over the region in question, where northern bowlders and modern sea shells are grouped together, that no doubt can exist, that the phenomena were due to a submarine agency extending over a very large region. When we examine the details, very great diversities of composition are, it is true, observable in the arrangement and composition of the drift at different localities. Thus, in Cheshire, gravel, like that of a sea shore, containing marine shells, has been discovered by Sir Philip Egerton in several localities[1]; while throughout the long, low tract, recently laid open by the cutting of the Grand Junction Rail-road, the drift is a thick argillaceous mass, with here and there a few fragments of northern rocks, and at intervals sea shells. Varieties of equal or greater diversity occur throughout North Shropshire. About Marrington Green, seven miles north of Shrewsbury, it is mostly a heavy clay, though in other contiguous places a coarse gravel, in which shells have also been discovered. Near Wellington the fine gravel is still more abundant in shells, and the gravelly deposits on the north-western slopes of the Wrekin[2] are rich in various irregular layers of sand and gravel, the latter both coarse and fine, with many quartz pebbles and bowlders of granite and greenstone of northern origin, irregularly distributed with the shells. At this spot, between hillocks of northern drift, is a small patch of purely local detritus, consisting

[1] See account of this gravel with sea shells by Sir Philip Grey Egerton, Bart. Geol. Proc. vol. ii. p. 189.

[2] This locality was first noticed by Mr. Trimmer, to whom I am indebted for having called my attention to it. The inferences which he drew from the appearances at this spot, of a former terrestrial condition of this part of the country, which was supposed to have been covered with trees, and of its having been submerged by a sudden inundation of the sea, were the result of a hurried visit. Subsequent examination, in which I was assisted by Dr. Du Gard, having convinced me that the supposed stumps of trees covered by gravel, were nothing more than the sharpened stakes and piles of a road (probably the old Roman via leading to Uriconium (Wroxeter) over which some of the gravel from the adjoining hillocks had been thrown, I offered an explanation of the deceptive phenomena. (See Proceedings of the Geological Society, vol. ii. p. 200.) Mr. Trimmer has since acknowledged the error, into which he was drawn through the hurry of his examination, and I would not here have alluded to the fact, did it not show how much caution is required in examining such phenomena, when a geologist of Mr. Trimmer's ability, and who had thrown so much light on this branch of inquiry, was for a moment misled by the specious appearances at this spot. The accompanying wood-cut explains the case.




108.

*a.* Sharp sand and gravel, with granite bowlders, and forming hillocks. *b.* Swampy depression between the hillocks into which vertical piles had been driven. *c.* The piles and osier. *d.* Gravel thrown in from the adjoining hillocks to form the old road.

of foxy-coloured sandy loam, in parts gravelly, overlying reddish loam and finely laminated sandy marl with small pebbles of the adjacent rocks of trap, sandstone, and quartz. Again, on the banks of the Severn, west of Shrewsbury, where Mr. Trimmer observed fragments of shells, Mr. C. Darwin has recently traced them extending for more than a mile in the drifted matter at Shelton Rough. The same gentleman has also very lately observed them in the coarse gravel south of Shrewsbury[1], and at Little Madeley in Staffordshire. I have myself collected them in various parts of Shropshire[2], Cheshire and Staffordshire, likewise between Dudley and the Severn; while Mr. J. Allies has found them at Powick and Bromwich, on the right bank of the Severn; and at Kempsey on the left bank, three miles south of Worcester; and has thus supplied the proof required, of the former existence of an arm of the sea in that latitude. They are most abundant and best preserved at the last place, where they lie at a height of about 30 feet above the Severn, in a bed of wet sand, covered by about 12 feet of coarse gravel and supported by tenacious red marl, the fundamental stratum of the district.

On visiting this locality[3] I perceived that the overlying gravel consisted of much detritus of the surrounding country, including fragments of various Silurian rocks, syenite of the Malverns, small pieces of coal and grits of the carboniferous series; together with rounded pebbles of several varieties of granite, similar to those traced from the north through Shropshire and Staffordshire. The granite pebbles, however, are much the least abundant and never equal the size of the fragments of rocks derived from the neighbourhood, some of which have the dimensions of a man's head, though the mass of the accumulation is simply what would be termed coarse gravel. Here, therefore, the smaller and finer portions of the northern detritus are commingled with various rocks of the country through which the prevailing current has passed. From the proofs of land on each side, and from the position of the sea shells some miles south of Worcester, at heights of about 100 feet above the tidal level, there can be no doubt, that when this tract was submarine, the lower part of the country, extending south of Gloucester, was also under the sea. As, however, few or no vestiges of the northern drift can there be traced, we must suppose, either that the strength of currents setting in from the north was expended before that latitude was reached, or if ever deposited, that the materials have since been denuded, or covered by the more recent alluvia of the estuary of the Severn.

[1] I have several times looked into the deep gravel pits south of Shrewsbury, i. e. between that town and the village of Meole-brace, without observing certain fragments of shells which have been since detected there by Mr. C. Darwin. The gravel in question is very coarse, and the shells are consequently much broken and worn. The materials are varieties of the Silurian and Cambrian rocks of the adjacent districts, coal grits, &c., with minute pieces of coal, and a few fragments of granite of about the size of a man's head. The coarse detritus in which the shells occur is 20 to 25 feet thick, and soft regenerated red sand (purely local) appears beneath it.

[2] Mr. T. Eyton, whose works have already secured him a high place among zoologists, furnished me with shells from the fine gravel and sand at Orleton Hall near Wellington and from Marrington Green. (See Map,)

[3] In company with Mr. Strickland and Mr. Allies.

In the wide spread above described, these sea shells are accompanied throughout by gravel and bowlders of northern origin; and although, as before stated, the detritus is much attenuated as it passes southwards into Worcestershire, some of the largest blocks and in the greatest profusion, occur in the south-eastern extremity of Salop and adjacent parts of Staffordshire, points very remote from the source of the detritus.

The shells which I first collected were examined about two years ago by Dr. Beck, and pronounced by him to be *Buccinum reticulatum*, and another species, *Dentalium Entalis*, *Littorina littorea*, *Tellina solidula*, *Cardium tuberculatum*, *Cyprina Islandica*, *Turritella Ungulina* (Beck.), (*T. Terebra*, Auct.) with fragments of *Venus*, *Astarte*, *Donax*, and other genera in too imperfect a state to be specifically recognised.

These and all the other sea shells since collected in the range, with the exception of two species detected near Worcester (including *Turritella Ungulina*, *Cardium edule*, *Purpura Lapillus*, *Arca*, and others), are recognised by Mr. J. Sowerby and all the conchologists who have seen them to be identical with the species now inhabiting our coasts, and thus no doubt is left as to the comparatively recent epoch when the tract in question was submerged. Though very variable in their appearance, the accumulations containing these shells indicate, that they have resulted from long-continued, ordinary, aqueous action; and they present in general, much the aspect of great littoral deposits now forming on shores, where the causes of change are of an active character[1].

The shells which have been found at Kempsey near Worcester are *Turritella Ungulina* (Beck.), *Purpura Lapillus* (Lam.), *Anomia Ephippium* (Linn.), *Cypræa Pediculus* (Gmel.), *Trochus cinerarius* (Linn.), *Murex Erinaceus* (Gmel.), *Ostrea edulis* (Linn.), with *Bulla Ampulla* (Linn.), and an *Oliva*[2].

[1] The distinguished Danish naturalist, Dr. Beck, to whom I have alluded, and who happened to be in England when my memoir on this subject was read before the Geological Society, informed me that all the shells in question are equally found in the detritus which covers large tracts of his own country, which he has no hesitation in considering an ancient bed of the sea, and in which also large bowlders have been mixed up with smaller gravel and shingle. In this opinion he unites with Mr. Lyell, in showing a direct analogy to the present bottom of the Cattegat and Baltic. Again, on the point of the resemblance of our drifted English materials to shore deposits, I have the high authority of Mr. C. Darwin, who during five years constantly observed the nature of such accumulations on the coast of South America, &c. Since his return, he has investigated the heaps of gravel and shingle around his native town (Shrewsbury), and he assures me, that they are in no way to be distinguished from many shore deposits of the southern hemisphere.

In some of the beds of sand near the surface (environs of Shrewsbury) Mr. C. Darwin has traced vertical stalactitic cylinders, of the size of straws or less, filled with white friable calcareous matter, which he conceives to have been made up from the decomposition of the shells. I have frequently seen such cylinders in sandy loam though not often filled with calcareous matter, and I presume that they may have been formed by some animal, and subsequently filled by decomposition of the overlying materials, aided by aqueous action.

[2] As some doubt might be entertained concerning the curious fact of this ancient *collocation* of species of modern sea shells which *now* exist in very different latitudes only, I must state that both Mr. Strickland and myself, having narrowly sifted the evidence brought forward by Mr. Allies, are completely satisfied of its accuracy.

The *Oliva* was dug out from the very bottom of the gravel pit in the presence of that gentleman and Mr. Peake,

The conchologist will not fail to remark, that the last list presents an intermixture of several species common to our shores, with an *Oliva* and the *Bulla Ampulla*, shells now only found in warm latitudes. However singular it may at first appear, this fact is not inexplicable even by reference to existing causes, for if the view which we have been advocating concerning the former relations of sea and land in this tract be sustained, it follows that the climate of the Vale of Worcester, when a strait of the sea, probably approached to a comparatively warm character. Such shells, therefore, as the *Oliva* and *Bulla* might then occasionally, though rarely, occur. This view will be made more intelligible in the sequel.

The drift described in this chapter is found at very various levels. In the plains of Cheshire it lies from twenty to a hundred feet above the sea. In the hills around Shrewsbury and in Staffordshire it occurs at heights varying from 150 to 500 and 600 feet, while on the edge of North Wales it is nearly 1700 feet[1]. Before, however, we attempt to consider the method by which detritus formed of the *same materials*, and containing the same *species of shells*, and therefore evidently distributed at the same period, could have been placed at such very different levels, we must endeavour to work out an essential part of the problem, the position of the great erratic blocks. The shells and small materials may evidently have been accumulated in an estuary of the sea under ordinary circumstances, but were the accompanying great erratic blocks deposited also by tidal action? To this consideration the following chapter is principally devoted.

and on a recent occasion Mr. Strickland accompanying Mr. Allies found with him the *Anomia Ephippium*, having much of the nacre preserved, together with *Purpura Lapillus, Turritella Terebra*, &c.

The other shells were collected by a very honest and veracious person (the head workman). It must be recollected that the superior mass of coarse gravel is seldom cleared away to the low level of the running sand in which the shells occur, and hence they can be detected at rare intervals only. Finding the shells well preserved at Kempsey, where they lie in *wet* sand near the surface of the red marl; and on the other hand much decomposed and very fragile at Powick, where they are in *dry* gravel, Mr. Allies has suggested an explanation which seems to me well worthy of consideration. Where the gravel is porous and the water percolates freely, the shelly matter, he submits, being subjected to alternations of moisture and drought, is soon decomposed; but where it is imbedded in sand, which is *constantly wet* and not exposed to atmospheric variations, the most delicate species are well preserved, even retaining some portion of their colours and the "nacre" of the shell.

The same explanation applies, indeed, under modifications to all the shelly accumulations with which I am acquainted in Lancashire, Cheshire, Shropshire, Staffordshire, &c.; for wherever the accumulation is argillaceous and impervious to air and water, as in the new rail-road excavations in Cheshire, the hinges, &c. of the most fragile shells are well preserved, while in the porous loose gravel of Preston and other places we find little else besides the *Turritella Terebra* and those shells which best resist destruction.

[1] In a very instructive letter, Mr. Trimmer informs me, that in addition to the case of Moel Tryfan, he has detected sea shells mixed with granite pebbles, both in low cliffs on the south-western coast of Caernarvonshire, and also on Moel Fabau near Bangor, eight miles distant from the coast.

## CHAPTER XXXIX.

### NORTHERN DRIFT (*continued*).

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*On the position of the great Bowlders which characterise the Northern Drift, and on the method of their transport.*

THE northern drift, as distinguished by its materials and association with sea-shells of existing species, having been described, it still remains to inquire into the positions occupied by the great blocks or bowlders which form part of it, and to endeavour to explain *how* they could have been transported to the spots where they now lie[1].

Though of very general occurrence throughout the tract between the Cumbrian mountains and the parts of Shropshire, Staffordshire, and Worcestershire just described, the large granitic blocks abound in certain localities only. Thus, their great number on the hills near Preston and other parts of Lancashire, not far from the sources of their origin, has been adverted to; and the table land north-east of Liverpool may be further cited as richly strewed with them, sometimes of considerable size. In Cheshire they occur at intervals, but more as solitary bowlders than in heaps. In North Salop, on the contrary, and the adjoining parts of Staffordshire, they are found both isolated and in groups. On the northern face of Haughmond Hill and the north-western slopes of the Wrekin they are numerous, particularly at the former locality; while a few stray individuals extend southwards, lying on or near the surface of the other alluvia for a few miles south of Shrewsbury (Lyth Hill, Longden, Stapleton, &c.). These may be considered as short tassels prolonged from the edge of the fringe before described. The greater heaps, however, are lodged in Staffordshire, particularly in the district west of the Dudley and Wolverhampton coal-field. (See Map.) Large portions of the surface of the New Red Sandstone, between Bridgnorth on the west and Wolverhampton and Himley on the east, are so studded with these blocks as to be well worthy of a visit. In the tract extending from the hamlet of Trescot to the village of Trysull, in the south-western part of Staffordshire, their quantity and occasionally gigantic

[1] Mr. Greenough has marked upon his map the occurrence of these granitic bowlders in several inland places, nd Dr. Buckland has reasoned upon them in his Reliquiæ Diluvianæ. In certain districts where they were very numerous, they are fast disappearing through the labours of the Macadamites. The formation of good roads must, therefore, be admitted as a *vera causa* for their rapid disappearance in districts where other good materials are wanting.

dimensions (several tons in weight) may well excite surprise, seeing that they there occupy one of the most central districts of England. Here the farmer is incessantly labouring to clear the soil, either by burying them or by piling them up into walls or hedge banks, and his toil, like that of Sisyphus, seems interminable; for in many spots new "crops" of them, as it were, appear, as fast as the surface is relieved from its sterilizing burthen[1]. So great, indeed, is their abundance, that an observer, unacquainted with the region, would feel persuaded he was approaching the foot of some vast granitic range; and yet the source of their origin is one hundred and fifty miles distant! From this great central depôt, they are traceable into the estuary of the Severn in Worcestershire, till they appear as solitary bowlders, and finally are entirely replaced by gravel, in which small fragments of the same granite are intermixed with local detritus. (See p. 532.)

In this range, the blocks, as well as the shells and smaller gravel of which we have spoken, are found at all elevations from 50 to 400 and 500 feet above the sea. Their course has no relation whatever to the existing drainage of the country, for as they occur on the northern slope of the water-shed which separates the estuaries of the Mersey and the Severn, they have followed a direction quite opposed to the present line of drainage. Nor have the transverse, or east and west ridges and valleys, which form the present surface, been any obstacle to their progress from north to south, since the largest accumulations occur to the south of the crest which divides these estuaries.

Let us, therefore, endeavour to seek for a rational explanation of the method by which they may have been transported into such positions. In so doing we may first advert to the different theories already propounded to explain a phenomenon, which being very general in other parts of Europe, has given rise to much speculation. The earliest theory, usually called the "diluvial," supposed, that these blocks had been forced into their present positions by one or more tremendous inundations, passing over a subsoil which had been *dry land*. This theory was supported by able writers, who connected it with the account of the deluge recorded in the Scriptures, and thus gave it a great ascendency over the human mind. It is now, however, abandoned by almost every geologist. Independent of the physical improbability (may we say impossibility?) of the rise of waves sufficiently high and strong to propel these huge blocks across mountains and valleys, such an hypothesis has been shown to be inapplicable to large regions of the earth which have *never* been affected by any general rush of waters since their present configuration was assumed[2]. But, besides this, we have demonstrated, that in the region under review, not only are there no evidences

[1] I am indebted to Mr. Cotton of Claverly for directing my attention to many of these huge blocks in the environs of Abbotsford Hill. Seeing their great abundance in parts of the tract, and the difficulty of eradicating them, some of the farmers absolutely believe that they *grow* in the soil.

[2] Such as Siluria; Auvergne in France, &c. (See note, p. 511.)

of the existence of dry land anterior to the deposition of this drift, but that it contains marine shells of existing species, and has all the characters of submarine or shore deposits; in short, that it must have been spread out *beneath the sea.*

Another theory is, that these blocks, in common with the associated drifted materials, were transported by powerful currents, set in motion during the elevation of mountain chains. The geologists who have taken this view (which I also once adopted) have not sufficiently placed before us the probable condition of the physical geography of the country when these currents were in action. Without showing what portions of the present land were above and what below the sea, or what was the power of water under such conditions, they have only spoken generally of great debacles and abrading floods, thrown off upon the flanks of the upraised masses. Such causes may afford a true explanation in Alpine or mountainous regions where there are evidences of repeated violent action. The grooves on certain rocks of Scotland and other parts of the world appear also to prove that blocks have been driven along their surface in various directions by powerful *local* currents[1]. But although this theory may be applicable in such cases, it will not explain, in the region under review, the occurrence of *distantly* transported blocks, imbedded in *local* debris; for if currents sufficiently powerful to transport the blocks had prevailed, the local detritus and shells would have also been removed by the same action.

In our case, however, the blocks having certainly been deposited *under the sea*, and not transported over *previously dry land*, we get rid of much difficulty; but can we explain the phenomenon by the modern analogies of deltas and tidal currents? If we suppose a great delta, extending 60 or 80 miles southwards from the shores of the ancient Cumberland, and in which blocks of granite as well as other ancient rocks were commingled with the marine shells at the bottom of the sea, those who argue for the power of tidal currents may contend that, if a strait existed between England and Wales, the tide stream might have exercised considerable power in carrying materials, and that by comparison with straits in which tidal streams *now* flow, there might have been a preponderance of transporting force in *one* direction;—that as there can be no doubt, that all tidal streams have a stronger tendency to carry loose materials out to sea than they have to bring them back again, so the ancient tide streams, which from the distribution of materials have been supposed to flow and ebb in the straits of Malvern, may have had an effective transporting power from north to south; and lastly, that if the shore of the ancient Cumbria which skirted the trumpet-shaped arm of the sea extending into the straits of Malvern, formed a long inclined plane, a large portion

[1] For the details concerning the grooved and scratched surface of rocks see Colonel Imrie's account of the Campsey Hills, Trans. Wernerian Society, vol. ii. p. 35; Sir James Hall's memoir on similar phenomena in the neighbourhood of Edinburgh, Trans. Royal Soc. Ed., vol. vii.; also Dr. Buckland's commentary thereon, Reliquiæ Dil., p. 201 *et seq.*; and my notice of the scored surface of the sandstone of the oolitic series of Braambury Hill, Brora, Sutherlandshire, Trans. Geol. Soc., vol. ii. p. 257.

of the materials being derived from the southern end of that delta, would have been hurried along into the straits, strewing their bottom with a littoral deposit from the Cumbrian mountains. This explanation, suggested as a *possible* case[1], is attended with insurmountable difficulties in the one under consideration; for if we assume the delta to be only 50 miles in length (not a third of the distance to which the bowlders have been propelled), and that the slope of the delta did not exceed 3°, I am reminded by my friend Mr. Lonsdale that its southern end must then have lain at the depth of 13,000 feet below the level of the sea. The hypothesis of the sloping delta from the shores of Cumberland is, therefore, quite inadmissible. If this subject were fully entered upon, many other difficulties, as the occasional immersion of the blocks in fine sand, &c., might be suggested in inquiring how submarine currents of water can have impelled onwards these gigantic bowlders. It might also be objected that this ebbing and flowing of the tide is a complex question, barely within the limits of geological reasoning. If, indeed, it be assumed that the district occupied by water was open at each end, as I believe it was, then it is possible that the tides flowed in opposite directions; as in the Irish Channel, and to a much greater in the English. But I leave this abstruse point in the hands of those versed in the laws of dynamics, hoping that at some future time they may explain all the circumstances under which submarine currents may effect the distant transport of *large blocks*, or whether such transport is impossible.

A third theory refers the moving agent to ice, and originated, I believe, with Professor Esmarck of Christiania, from witnessing the conveyance of stones by icebergs during the thaw of glaciers, and their gradual advance upon adjoining plains. This theory, being confined to *subaerial* phenomena, is of course inadmissible in our *submarine* case. A new application of the same principle was suggested by M. Engelspach de L'arrivière[2], who from an observation near the mouth of the Niemen was led to believe, that icefloes sailing out from rivers into seas, may, from the specific lightness of the ice, have borne along many large blocks of stone and deposited them at great distances. This opinion, being founded on the observation of a large block of granite so circumstanced, is well worthy of consideration, particularly since the theory has been much improved by Mr. Lyell, who, combining this and other data, has shown that wherever icebergs and icefloes have existed, this method of transport is unquestionably a *vera causa.* The same reasoning may be applied to all those regions in which, from their physical features, we may be sure that the cold is, or has been, sufficiently intense[3].

[1] In a letter from the Rev. W. Whewell to myself, 1836, after my memoir on this subject was read before the Geological Society. This ingenious letter contains much additional matter, which may, I hope, appear hereafter in some work by Mr. Whewell, who having since been elected President of the Geological Society, will I trust show us to what extent physical science *can* be correctly applied towards explaining geological phenomena.

[2] Considérations sur les Blocs Erratiques. Bruxelles, 1831.

[3] See Charpentier and Venetz on the Glaciers and "Moraines" of the Alps. Professor Agassiz has also

*Once let it be granted*, that large frozen masses, like those now periodically liberated from the polar regions, were drifted to certain distances and in given directions by currents dependent on former configuration of the land, and we are furnished with an adequate agent; each icefloe as it dissolved, might have dropped its load of stones, at intervals, upon a submarine surface of gravel, sand, and shells. From the observations of Scoresby, Bayfield and others, we know that such operations are going on to a great extent in the Atlantic, floes being sometimes wafted to very southern latitudes before they are finally dissolved. This fact, indeed, was brought before the public more than a century ago by Bradley[1], who, having learned from seafaring men, that between our shores and the "Plantations," large islands of ice were sometimes met with, inferred, that the vapour arising from their dissolution, must have had a sensible influence upon the climate of England! Had geology been then a science, some Lyell might have seized upon this fact for the support of a wider induction than a meteorological theory.

But can we venture to adopt the icefloe hypothesis to explain the position of our Salopian bowlders? Have we a right to assume that the physical features of this region were formerly so different from the present, that ice may then have been formed in adequate quantities on the shores of Cumberland? I confess that on the first consideration I was disposed to reject such views as visionary, but reflection and reference to facts have led me to perceive, that many strong arguments may be employed for their adoption. In the first place, it might be said that even with the present amount of land and sea, the cold of our latitudes has at times been intense enough for the production of enormous masses of ice[2]. It might be argued that such frosts as those which congealed the Danube from top to bottom, which closed the Dardanelles, or rendered the Adriatic one sheet of ice, may have acted, in times long anterior to historic records, on the shores and rivers of Cumberland, Scotland, and Ireland; and that the ice islands set in motion at the termination of such frosts may have strewed their contents over the bottoms of adjacent seas. If, however, such causes be not deemed sufficient, the geologist may go much further in his endeavours to solve the problem. Knowing that great changes of sea and land *have* occurred within recent periods, and witnessing the mighty wreck of materials of the solid strata distributed on all sides, he may venture to suggest, that when England and Wales were separated, the distribution

recently expressed some peculiar opinions on the action of ice upon the Jura, &c. Cases purely subaerial, like these, can, however, have a collateral relation only to my submarine examples.

[1] "A Survey of ancient Husbandry and Gardening," Oct. Lond. 1725, by Richard Bradley, F.R.S., and Professor of Botany in the University of Cambridge.

[2] In the year 1709 all the rivers and lakes were frozen, and even the seas to several miles from the shore. The Adriatic Sea was quite frozen over, and even the coast of the Mediterranean about Genoa. In the year 1740 an ox was roasted on the Thames. In 1658 Charles X. of Sweden crossed the Little Belt with all his army and artillery, &c. For a full list of all the great frosts and excessive heats, see Edinburgh Review, vol. xxx. (No. lix.) p. 23 *et seq*.

of land and sea may have been such, as to have permitted the production of icebergs, which, being dislodged from the shores of Cumberland, might have been drifted into the straits of the sea then existing to the south of Bridgnorth.

If, however, we admit that icefloes or icebergs may have been the true method of transport, it is right to allude to an objection which has been raised, that the blocks in Shropshire (as in many other parts of the world) are generally so much rounded and worn, that they rather convey the impression of having been rolled under water, than of having been simply removed from their parent rocks in vessels of ice. Now, although this objection cannot be altogether obviated by replying, that modern atmospheric agency may have worn away their angles and scored their surfaces, (for we sometimes witness the same appearances when the bowlders are dug out from great depths beneath gravel, clay and sand) still the attrition of their surface may be well explained under any one of the following conditions. 1st. They may have been carried down by streams to the shores, and have been long bowldered there, *previous* to their insertion in the ice. 2ndly. They may have been fragments, which, falling from the adjacent rocks, were exposed to the action of water on the shores before their transport by ice. 3rdly. It is well worthy of remark, that granite is so prone to desquamation[1], that nearly all granitic chains are topped with *rounded* masses, which, though really *in situ*, have often the appearance of being bowlders; and these, if dislodged from cliffs and imbedded in icefloes, would at once present the appearance objected to, though they had *never* been rolled under water. Finally, it may be observed, that if transportation in ice be supposed, we can account rationally for the blocks occupying for the most part the surface or upper portions of the drift, for we know from modern analogies, cited by Captain Bayfield, that icefloes, in narrow bays or straits, are generally stranded on coasts or shallow shores.

Such were the arguments I employed to show how far the ice theory would account for the dispersion of erratic blocks over the central parts of England[2]. Others had put forth this theory in respect to fluviatile, lacustrine, and subaerial phenomena, and I applied it to the ancient condition of the region in question, when it *was permanently beneath the sea*. But still, in common with other geologists, I was unprepared with adequate data to show how such phenomena could have occurred in our latitudes during the period before the present, while geological evidence went rather to prove the prevalence of a former higher temperature[3]. No one, in short, had then the *means* of ac-

[1] See Macculloch on the Tors of Cornwall, Geol. Trans., Old Series, vol. ii. p. 66.

[2] The memoir containing these views was read before the Geological Society, in 1835, and was subsequently commented upon in Mr. Lyell's Anniversary address, Feb. 1836. (Proceedings of the Geological Society.)

[3] The erratic blocks on the surface of the earth are *so much larger* than any fragments found within the ancient strata, that some geologists have termed the epoch of their production "the block period," ("Période Clysmien" of Brongniart). It is quite manifest that as far as our present evidences teach us, the period n which these blocks were transported *differed essentially from any which preceded it*, and the difference can only be well accounted for by a prodigious change of climate. Geologists, therefore, naturally connect the absence of these

counting for the existence of ice in such latitudes, except by referring to the great vicissitudes of European climate within the range of modern history. Yet how inade-

blocks in the older strata with the higher temperature which, from other independent reasons also, was then supposed to exist, and their presence in the modern æra with a diminished temperature. This accordance of geological data with the result of an icefloe hypothesis is further borne out by modern analogies; since, as far as our inquiries go, no far transported large blocks have yet been found on the surface of equatorial regions.

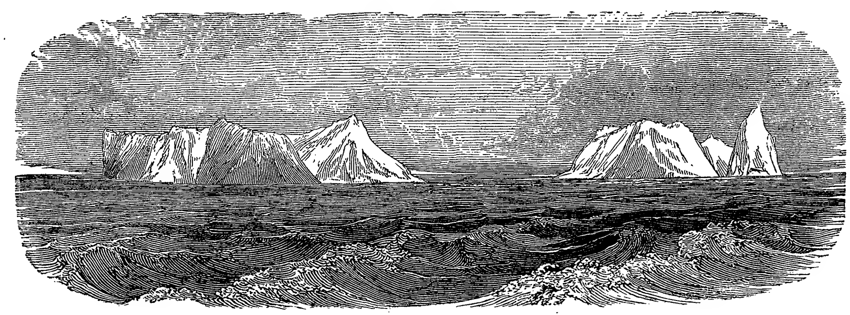
The preceding paragraphs in the text, including the first part of this note, were read to the Geological Society just as they are printed; and when I had no hope that the views they contain would have been so well sustained as they have since been by modern analogies. (See next page.) I still adhere to my belief, that there is yet no established case of far transported large bowlders in tropical regions; but from fresh sources of information I am led to suppose that the partial discovery of bowlders in such tracts, so far from weakening the icefloe hypothesis, would almost support it by evidence drawn from existing causes.

In 1836, Captain Octavius V. Harcourt, R.N., returning in the North Star from South America, met with a vast number of icefloes in the Pacific, in latitude 50°. Some of them were not less in size than two miles square and 250 to 300 feet above the water. It is remarkable that this phenomenon occurred from 85° west longitude, at a considerable distance from any land, to the meridian of Cape Pillar; while the immediate coasts of Chiloe and Cape Horn offered no trace of them. The winter was comparatively mild, which might indeed account for the liberation of such large masses of ice from the South Pole, and their being wafted into seas usually quite free from them. The number and size of these icefloes were truly astonishing (two of them as seen for a distance of three to four miles are represented in the wood-cut below), and Captain Harcourt had the greatest difficulty in so steering, during the long winter moonless nights of 18 hours, as to avoid shipwreck. Their course seemed to be from south-east to north-west, and they were met with through five degrees of latitude (50° to 55°), which would be *the exact position of England if transferred to the other hemisphere.* Their occurrence was accompanied by sudden changes of wind and violent tempests. (Abridged from a letter of Captain Harcourt to myself.)

In the 7th Volume of the Journal of the Royal Geographical Society icefloes are mentioned by Mr. Bennett (p. 212.) in latitude 47° south, and they have even been met with recently as high as 35° south latitude, the parallel of Bengal in our hemisphere.

The multitude of these icefloes sailing together for such a great distance from the source of their origin before they are dissolved, not only teaches us, that any stones of the polar region which they might be transporting, must now form part of submarine deposits, even in intertropical regions, but also explains how a vast number of such stones *might* be collocated in *one* tract very remote from the parent rock, as in the south of Staffordshire, p. 536 (*ante*). See Lyell's excellent illustration of this point, Principles of Geology, vol. iv. p. 267. According to this author the mass of ice below the level of the water in floating islands is seven or eight times greater than that above, and hence the islands here represented must have had a total altitude of from 2000 to 2500 feet! (See Scoresby's Voyage, p. 233.)

109.



*Icefloes in the Pacific, from a drawing by Captain Octavius V. Harcourt, R.N.*

quate was that cause to explain such widely spread effects! Doubtless, if the phenomena had been rare and confined to one part of Europe, a partial deviation from the ordinary course of nature might explain it; but how are we to reconcile the position of blocks which had been transported from Savoy to the Jura, or from Scandinavia to the plains of Prussia, with such a method of explanation? Notwithstanding the attempts to apply the iceberg theory generally in aid of the transport of submarine blocks (seeing that in northern latitudes it was a *vera causa*), still geologists were wholly unprovided with data to reconcile the former action of ice, in latitudes where it does not now occur, with a former condition of Europe favourable to tropical productions: and this argument was vigorously pressed home by the opponents of the theory. In this state of the subject, Mr. Charles Darwin, who accompanied Captain Fitz Roy during five years throughout the southern hemisphere, returned to Europe, with the knowledge of many novel facts bearing upon this and other geological questions. In his journal during the voyage of the Beagle about to be published, and to some pages of which I have had access, after giving examples in low latitudes in the southern hemisphere, he fairly establishes this proposition:—that an equable climate, probably a direct consequence of a large proportional area of water (a probable condition in the geological case under review) is at the same time favourable to the presence of tropical productions, and to a low limit of perpetual snow, and therefore to the descent of glaciers into the sea in latitudes as low as 46° 40′. (pp. 283—285.) Judging from these examples, he infers, that the dispersion of floating masses of ice, with included fragments of rocks, descending from the mountain chains of central Europe, where islands alone formerly prevailed (the case above supposed), might absolutely have been anticipated to have taken place during the period before the present. Referring my readers to the original observations of this clear and powerful reasoner for the details of the phenomena in the southern hemisphere, by which his inferences are supported, I will here quote his principal conclusion, drawn from the unanswerable facts, which he ingeniously applies to explain the transport of great bowlders.

"The circumstance of a luxuriant vegetation, with a tropical character so largely encroaching on the temperate zones, under the same kind of climate that allows of a limit of perpetual snow of little altitude and consequent descent of the glaciers into the sea is very important; because it has been argued, with great apparent truth, that as there is the strongest presumptive evidence of a gradual cooling down of the climate (or rather of a less favourable state for tropical productions) in Europe, it is most unphilosophical to imagine that *formerly* glaciers could have acted where they do not *now* occur. It may be asked, what are the circumstances in the southern hemisphere that produce such results? Must we not attribute them to the larger proportional area of water; and do not plain geological inferences compel us to allow, that during the epoch anterior to the present the northern hemisphere more closely approached to that condition than it now does? We are all so much better acquainted with the position of places in our

own than in any other quarter of the globe, that I will recapitulate what is actually taking place in the southern hemisphere[1], only transporting in imagination each part to a corresponding latitude in the north. On this supposition, in the southern provinces of France, magnificent forests, entwined by arborescent grapes, and the trees loaded with parasitical plants, would cover the face of the country. In the latitude of Mont Blanc, but on an island as far eastward as central Siberia, tree-ferns and parasitical *orchideæ* would thrive amidst the thick woods. Even as far north as central Denmark, humming-birds might be seen fluttering about delicate flowers, and parrots feeding amidst the evergreen woods with which the mountains would be clothed down to the water's edge. Nevertheless, the *southern part of Scotland* (only removed twice as far to the westward) would present an island, 'almost wholly covered with everlasting snow,' and having each bay terminated by ice-cliffs, from which great masses, yearly detached, would sometimes bear with them fragments of rocks. This island would only boast of one land bird, a little grass and moss; yet in the same latitude the sea might swarm with living creatures. A chain of mountains, which we will call the Cordillera, running north and south through the Alps (but having an altitude much inferior to the latter), would connect them with the central part of Denmark. Along this whole line nearly every deep sound would end in 'bold and astonishing glaciers.' In the Alps themselves (with their altitude reduced by about a half) we should find proofs of recent elevations, and occasionally terrible earthquakes would cause such masses of ice to be precipitated into the sea, that waves tearing all before them would keep together enormous fragments, and pile them up in the corners of the valleys. At other times, icebergs, 'charged with no inconsiderable blocks of granite[2],' would be floated from the flanks of Mont Blanc, and then stranded on the outlying islands of the Jura. Who then will deny the possibility of these things having actually taken place in Europe during a former period, and under circumstances known to be different from the present, when on merely looking to the *other hemisphere we see they are among the daily order of events?*" (p. 291 *et seq.*)

But Mr. Darwin is not satisfied with showing, that the coasts of former European islands were in all probability the seats of great icebergs; he pursues his argument further, and in common with other geologists points out the *absence* of erratic blocks in the intertropical regions (where glaciers and icebergs could not have acted) as a corollary of the great geological problem towards solving which he has done so much, by an appeal to existing nature[3]. The above observations, therefore, show, that *there are* conditions in which ice may be accumulated and become a motive power; and that such

[1] It is in the southern hemisphere that we find elephants, rhinoceroses, hippopotomuses and lions, as far south as latitude 34° and 35°. In South America the jaguar occurs in 42°, the puma in 53°.

[2] Captain P. King, R.N. uses these words when alluding to the case in Sir G. Eyre's Sound, which Mr. Darwin has more fully described from the information of Mr. Bynoe.

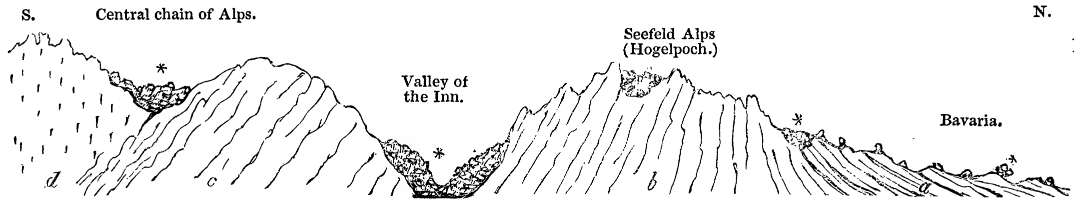
[3] See my note on this point, p. 541.

conditions *may* have existed in our latitudes when there was a very different proportion between land and water. Following up the important observations of Humboldt and Lyell, upon the influence of continental masses and great seas upon climate, Mr. Darwin materially adds to the cumulative proofs, that temperature is not dependent solely upon latitude.

Thus, the conditions of the difficult problem which we have to solve are now much more fully brought before us than in any former discussion of the subject. We have in running water a power, the extent of which has, however, yet to be worked out. We have also a *vera causa* in the icefloe, which, it appears to me, goes *much further* towards explaining the difficulty, than any hypothesis which has yet been framed; although it would, perhaps, be premature to assert that it completely settles the question, still less that such agency can be considered the only one by which bowlders may have been transported.

It still remains for us to say a few words on the present relative heights at which the bowlders occur, although, if their deposit by icefloes be admitted, much difficulty is obviated, as the bottom of a sea in which the bowlders were dropped, may have often been so full of inequalities, as to present, when desiccated, an outline similar to many of our undulating and even hilly countries. But the striking and sudden differences of altitude at which these blocks and shells are found, in the same district, seem to call for additional explanation. The difference of height between the top of Moel Tryfan, and the plains of Salop and Cheshire (1400 to 1600 feet), is almost too great to admit of the supposition that such was the submarine surface. If, indeed, we admit that in this district, such vast submarine inequalities existed, still we should have to account for others of much greater amount in foreign countries[1]; and, therefore, it is

[1] Illustrating the apparently inexplicable position of certain bowlders in relation to the *present* outlines of the earth's surface, I would cite one of many cases which have fallen under my observation in and upon the flanks of the Alps.




110.

This wood-cut represents a transverse section across the Tyrolese mountains which flank the valley of the Inn west of Inspruck. To the south, the older transition rocks (*c*) are flanked by the granitic nucleus of the chain (*d*). To the north are the great masses of limestone (*b*) (crystalline and dolomitic), which representing our oolitic series and lias, attain heights of 6000 feet above the sea, and beyond them the lower hills of green sand (*a*) and tertiary deposits of Bavaria. In one of the loftiest combs of the Alpine limestone, called Hogelpoch, considerably above Seefeld, and at a height of at least 3000 feet above the valley of the Inn, is an accumulation (*) of blocks of gneiss, granite, porphyry, chlorite slate, &c., materials which can have been derived only from the central mountains (*c* and *d*), and from which they are now completely cut off by a deep valley. My present belief is, that there was a period in which the blocks in the valley and those on the summits of the

desirable to search for more valid reasons to explain the difference of levels. Geology furnishes us with these, in teaching us that our present lands have been irregularly raised from beneath the ocean[1]. Some regions have been heaved up in the form of great plateaux without many breaks; but the vastly larger proportion of the crust of the globe is absolutely starred through with rents (many examples have been cited in this work), by which beds once continuous have been snapped asunder, and subsequently moved up

limestone mountains, were deposited under water in the form of a delta, extending northwards from the central chain, during the formation of which the blocks overlying the limestone peaks were probably at no very different level from those now lying on the banks of the Inn.—That after the drift had been so deposited, powerful movements took place, heaving up the outer shores and raising the pre-existing bottom of the sea, estuary, or lake (as the case might be) to great heights, the blocks and loose materials being thus left at various elevations, and in the detached positions in which we now find them. Here, we have no occasion to *imagine* dislocations, for they teem in every mass of rock. The chasm in which the Inn flows, is indeed *one great line of fault*, and such are the contortions and dismemberments of the whole chain, that throughout more than 50 *miles* from east to west, the younger formations are thrown over and appear to dip under the older! But even with such evidences of mutation, I confess that in the year 1828, although I *then* believed that the phenomenon I am describing, could be explained only by movements of unequal elevation and depression, I was not prepared to go the length I now do in the solution of this problem, my present views being founded on the knowledge, *since* acquired in England, of the intermixture of sea shells of unquestionable modern species with erratic blocks. Now, although the rationale of icefloes, as above propounded, has rendered our appeal to catastrophes uncalled for in many cases, we cannot witness the scenes of dislocation in the Alps, and perceive that they are accompanied by the lodgement of bowlders derived from the same source at heights so different, without also employing such evidences of mutation to help us in part to solve these problems. If some of the greatest relative changes between the sea and land have taken place in our island within the modern period, the same may have also happened at a comparatively recent period in the Alps*.

[1] I could have strongly illustrated these views by an appeal to evidences of recent elevations of the shores of South America, but as this inquiry would lead me beyond the limits I have prescribed to myself, I must refer my readers to Lyell's Principles of Geology, or for details to the works of Mrs. Graham (now Lady Calcott), Mr. Caldcleugh, Dr. Meyen, and above all to the clear and unanswerable record of that distinguished navigator and precise observer, Captain Fitz Roy, R.N. In describing the effects of the last earthquake at Concepcion (Geographical Journal, vol. vi. p. 327.), Captain Fitz Roy has distinctly proved, that the island of Santa Maria was elevated from 9 to 10 feet, while the rest of the coast on the mainland was only raised from 2 to 4 feet; and thus we see that not only in the same epoch, but absolutely during the same minute, recent sea-shells lying in the same bed were placed at very different levels. This small measure explains the *modus operandi* as well as if the scale had been equal to that of the ancient phenomena under consideration.

The reader will have perceived in various parts of this work, that while I rejoice in what I would call the "Lyellian method" of testing geological phenomena by modern analogies, I do not believe in the doctrine, that the dislocations of the present day are produced by causes of the same degree of *intensity* as those of which geology affords the proofs. I must always be of opinion that, although they may belong to the same class, the geological catastrophe (such as the *overturning of a mountain chain*) and modern earthquake cannot be placed side by side, without our exclaiming "*sic parvis componere magna.*"

* See observations by Professor Sedgwick and myself on the Eastern Alps, Geol. Trans. vol. iii. p. 415. The bowlders of Hogelpoch were observed by myself in a previous visit, but they form a part of the detritus referred to in our joint memoir.

and down to widely different levels. Is it not, therefore, a fair inference, that during the recent elevation of the continents and islands over which these bowlders are distributed, there must have been movements of very different degrees of intensity, at comparatively recent dates, affecting the different portions of the tracts in question? If partial elevations at some points and depressions at others, occurred during the desiccation of the bottom of the sea (and it is obvious such changes must have happened), many of the submarine valleys and hills must have thereby been much modified.

Adhering, therefore, to the prevalent belief of modern geologists, founded on a multitude of *well-recorded facts*, that the land has been repeatedly elevated and depressed in relation to the sea level, I confess my inability to imagine how such mutations can have been accomplished without involving, as a necessary result, the repeated fracturing of all the subjacent strata. In viewing the present surface, we are not to expect that the loose materials of the bed of the sea should, when elevated, exhibit lines of fault, as clearly and neatly defined as those impressed upon the solid strata which support them; the only memorials we could expect to find of the dismemberment of the loose aggregate, being what we now witness;—the separation and removal to various heights of gravel beds which were once continuous. For we must recollect, that under the view here adopted, the space between the elevated and stationary parts, or between those elevated and depressed, would always be exposed to the same action as a *sea beach*, and therefore such portions would be rounded off, and the final result would be the appearance of a covering spread more or less equably over the whole tract. Such elevations in throwing off large bodies of water must, it has been shown, have materially aided in the partial transport of many of the fragments.

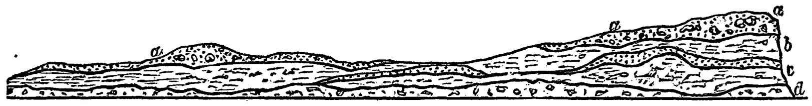
Lastly, elevations to the extent we have now supposed, can hardly have affected so large a portion of our western shores, without producing a great effect on the relations of land and sea on the other coasts of the island; and as from collateral evidences we already know, that great part of our eastern shores was submerged at an equally modern period, because the same species of sea-shells are there also found in gravel, we may infer that, by whatever means accomplished, the estuaries of the Humber and the Thames, and the coasts of Devonshire and Cornwall, were desiccated during the same period as the plains of Shropshire and the estuaries of the Mersey and the Severn[1].

[1] See a memoir by Professor Sedgwick and myself on the raised beaches of Devon and Cornwall, Geological Proceedings, vol. ii. p. 441. Similar raised beaches, inclosing sea-shells of existing species, have been observed at various points along the eastern shores. See memoirs by Mr. W. Hamilton on the shores of Fife, Geological Proceedings, vol. ii. p. 180.; by Mr. Prestwich on the shores of Banffshire, Geological Transactions, vol. v. p. 139.; by Professor Phillips on the coast of Yorkshire; and by Mr. Smith, of Jordan Hill, Geol. Proceedings, vol. ii. p. 427., on the western shores of Scotland. The last-mentioned gentleman has very much enlarged our knowledge of this subject by very extensive collections and accurate determination of the species of shells. I may also mention a raised beach at Cranfield Point near Carlingford, Ireland, observed by Professor Sedgwick and myself, in company with Mr. Hamilton and Mr. W. D. Hull, in the summer of 1835, as its component parts and general aspect much too closely resemble the coarse and fine accumulations

These great mutations are, therefore, appealed to as the cause, by which in raising up large submarine tracts and uniting islands into continents, the climate of our region has been materially changed; while they satisfactorily explain to us why the agency now at work around us differs in so many respects from that of the period which preceded our own.

of Lancashire, Cheshire, and Shropshire to be passed by without notice on this occasion, particularly as this part of the coast of Ireland is precisely in the same latitude as the Cheshire and Salopian detritus.

111.




*a* and *b*. Vegetable mould, sand, and gravel, with shells similar to those found in the adjoining sea—18 feet above high water mark. The pebbles resemble shingle. *c*. Clay, with occasional coarse fragments of porphyry, limestone, granite, &c. *d*. Gravel as above repeated.

The late Major Patrickson described this raised beach in a memoir read before the Geological Society of Dublin. Similar beds of recent marine gravel have been observed in different parts of Ireland by Griffith and other observers.

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[After the proof sheet of this chapter had passed from my hands, Mr. Lyell sent to me a letter from Capt. Bayfield, R.N. (now employed in surveying the coasts and rivers of our North American colonies), which so powerfully sustains the views I have adopted, concerning the transport of bowlders by ice, that an extract from this instructive and interesting letter will be printed in the Appendix.]

# CHAPTER XL.

## SUPERFICIAL DEPOSITS (*continued*).

*Early condition of the surface after elevation from beneath the sea.—Lacustrine and broad river period.—Passage to present condition.—Remains of extinct species of quadrupeds.—Ancient river deposits.*

WE have now to ascertain the changes which the surface has undergone since large masses of land were raised from beneath the sea. In this inquiry I shall endeavour to explain first, the transition from ancient to modern phenomena, showing why the latter must have mainly resulted from the former, in consequence of alterations in the relative level of land and water; and secondly, the modern terrestrial changes and accumulations. In this attempt to connect in one series the operations which took place during an early condition of the surface with that which now prevails, the following subjects will be successively examined in this and the subsequent chapter. 1st. The early condition of Siluria shortly after its emersion from the sea, when that region must, it is supposed, have been in great part irrigated by lakes and broad rivers. 2ndly. How such great water courses have been diminished. 3rdly. The proofs that Siluria on the one hand, and parts of England on the other, were inhabited by early races of quadrupeds. 4thly. The desiccation of lakes and turbaries within the historic æra. 5thly. The modern action of rivers. 6thly. The periodical floods of sand, and effects of great storms, &c. 7thly. Terrestrial accumulations, such as shell marl, travertine, &c.

In this chapter the reader must figure to himself the condition of the surface, immediately after the rise of the land from beneath the sea, when large hollows were occupied by water which has been subsequently let off by transverse gorges, and the lowering of the river-courses to their present levels[1].

[1] In speaking of lakes I make an application of the term which some geologists may perhaps disapprove of, seeing that no zoological proofs of lacustrine deposits are brought forward. Still as the occurrence of fine silt and sand in embayed flats, thus distinguished from the coarse drift before described, can in no way be explained, except by the tranquil occupation of water, I am compelled to believe that in the intermediate period between the elevation of the bottom of the ancient sea and the establishment of the present drainage, such tracts were in fact lakes, which have since been let off.

*On the earliest fluvio-lacustrine deposits of the present surface.*

The Silurian region contains many low flats, so equally and horizontally spread over with fine sand, silt, and flattened shingle, and so surrounded by hills, as to induce the belief, that they have been occupied by water since the land assumed its present configuration. The triangular valley extending from Wigmore to the escarpments of the Ludlow promontory, and called the Wigmore Lake (see p. 238.), is a good example. It is bounded by the hills of Brindgwood Chase on the north, by those of Croft and the Vinnals on the east and south-east, and by Wigmore Rolls upon the west. Only a sluggish rivulet now drains the surplus water and conveys it to the Teme. This river, after meandering in an alluvial flat (Leintwardine bottoms), connected with the north-western extremity of Wigmore Lake, escapes to the plain of Ludlow through the deep transverse gorge of Downton on the Rock. If this fissure were suddenly dammed up, the waters of the Teme would overflow the whole of the low country, including the triangular space of Wigmore Lake. The fine silt and sand even now adhering to its sides, at Leinthall Starkes and Elton, indicate that water must for a long time have occupied this cavity[1]. In Leintwardine Bottoms we find a top layer of good brown loam, covering sandy and argillaceous earth, and passing downwards into a stiff silt, sometimes containing leaves and sticks, while beneath this and six feet below the surface, is a fine gravel of a lacustrine character, and the lowest stratum is a running sand in which water rises. The real subsoil of all this low tract is the Wenlock shale, which, where not covered with the above alluvial sediment, disintegrates to a most unmanageable clay[2]. On first inspecting the physical features of the district it might appear, that ancient currents must have passed from this depression, through the transverse valley in which the river Lugg escapes by Aymestry into the plain of Old Red Sandstone; the land between Wigmore and Aymestry being encumbered with hillocks of coarse drift, made up of fragments of all the adjacent rocks and deposited at different levels. Now, in all probability the violent operations which upheaved the Ludlow promontory from beneath *the sea*, and threw it into an anticlinal form, produced

[1] It has before been shown that this valley is one of elevation, and it is also one of denudation, for no loose materials belonging to the rocks which form its sides are to be found within it. Unlike, however, the valleys of Woolhope, p. 436, and of Prescoed, near Usk, p. 441, this hollow is open on *one* side, namely, the north-west, or the quarter whence the ancient marine *drift* of this region has been shown to proceed; and hence, as might be expected, a few bowlders and fragments of the rocks of the Caradoc and Longmynd, are to be seen on the face of a rising ground near the centre of the denudation.

[2] To the north-west of Leintwardine, the valley of Clungunford connected with this depression of Wigmore by that of Leintwardine, lies at a higher level, and is filled with much local detritus, sometimes arranged in the following descending order: *coarse gravel* with bowlders of the adjoining rocks 10 feet; *sand* 4 feet; *clay* depth unknown.

the gorge of Aymestry, and at the same time choaked it up with this coarse detritus, which was thus one of the immediate causes of the formation of the Wigmore Lake.

The Lugg prevented by the escarpments near Lingen from continuing its south-easterly course is, indeed, deflected to the *E.N.E.* until it reaches the Aymestry gorge, through which it escapes into the plains of Herefordshire; while it is completely cut off from all communication with the Wigmore Lake by the high mounds of ancient gravel above adverted to, and also by the undulating form of the subsoil. Not so with the Teme, for the same movements of elevation which raised the Ludlow promontory, and heaped up the detritus in the gorge of the Lugg, doubtless also produced the fissure by which the Teme issues into the low country; leaving it, however, unencumbered by any coarse drift. This fissure, which in earlier days, could with difficulty have afforded a passage to its waters, must (judging from the present rapidity of this river in floods,) have been subsequently so much deepened, as to complete the drainage of Wigmore Lake and Leintwardine Bottoms. Of this, indeed, there can be little doubt, since it is well known that within the period of history a large portion of the "Wigmore Lake" (the name by which it is still known) was a mere profitless marsh, the superfluous waters of which have since been drained off through the channel of the Teme.

In its course to the east, the Teme offers another example of having been barred up, and of having given rise to a lake, lower than that of Wigmore. To the east of the town of Tenbury, finely laminated alluvia form low terraces, about twenty feet above the present bed of the river. These materials appear to have been accumulated under tranquil water, and the form of the depression supports the hypothesis; for the whole of the valley between Tenbury and the Abberley Hills, might even now be suddenly converted into a lake, by merely shutting up the gorge of Knightford Bridge, the only transverse fissure in the chain of Silurian hills extending from Malvern to Abberley, through which the waters of the north-west part of Worcestershire and the north-east of Herefordshire can find their way into the valley of the Severn. (See Map.)

It is to be presumed, indeed, that many of the rivers which now pass through gorges to the south-east, from the Welsh mountains on the north-west, must, when fluviatile action commenced, have been flooded back, and have caused lakes; for we cannot examine the finer detritus spread over the flats and basin-shaped cavities in which the Wye, the Onny, or the Lugg meander, without attempting to explain the phenomena in this manner. The low lands around the town of Hereford, particularly where the Lugg empties itself into the Wye, offer one of the clearest examples in the drainage of this region, where such sheets of water must have had a character intermediate between fluviatile and lacustrine. Deep red silt and clay, the detritus of the marl of the Old Red System, here constitute to a great depth a wide area of low and fertile land. That this sediment was carried down during many ages by the Lugg, may be well imagined on inspecting that red and turbid stream, when flooded. It empties itself into the Wye at so low a level, that when swollen by heavy rains, the great volume of its

waters is ponded back, and spreads over the low lands between Stoke Edith and Hereford, and thus presents an exact picture of that state of things, which must have had a long continuance in the earlier periods of the existing surface, before the channels near the mouths of the rivers were *sufficiently deepened* to afford an easy exit to their waters. The whole extent, indeed, of the flat country of the Wye around Hereford affords strong evidence, that there was a period when the waters of the river, being partially dammed up, produced a lake of great magnitude, which can have been reduced to a simple river only, by the deepening of the gorges between Ross and Chepstow.

Besides these evidences of lacustrine and broad river accumulations in Herefordshire, and the adjacent parts of Salop and Worcester, the more mountainous regions of the Welsh borders present many deposits of fine silt and shingle, the nature of which seems to be best explained, by supposing the cavities in which they occur to have been occupied by water, which was little agitated during long periods. In the vale of Radnor, for example, there is now only an insignificant rivulet; yet its level surface, and the character of its alluvium indicate, that it was long submerged. The appearances in the embayed flat around the town of Presteign would also induce us to suppose, that the fine debris with which it is strewed, was similarly accumulated. The Vale of Montgomery, though encumbered in parts by coarse detritus from the adjoining hills, may also in great measure have been covered with its present alluvium, by lacustrine waters collected from the want of a ready egress of the Severn to the north, or of the Onny to the south-east[1]. There are strong evidences, indeed, of a lacustrine deposit in a depression connected with the Vale of Montgomery, and between the Long Mountain and the Cornden Hills, filled as it is by a dense and deep clay with partial peat bogs, from which large trees have been extracted. The drainage of this tract is now effected by the Camlet, a sluggish, small stream, which, rising in the Shelve Hills, descends into the vale of Bishop's Castle, where it divides; the principal branch the Onny, running eastward in the direction of the main or *coarse gravel drift*; the other, bending back as it were upon its former course, flows to the N.N.W. in a deep and narrow ravine called Marrington Dingle[2]: it is afterwards deflected to the south and west by a low barrier,

[1] The basin-shaped form of the Vale of Montgomery and other similar depressions in Silurian shale or mudstone, have led some persons to imagine that they might contain *coal*; and Mr. More of Linley bored many yards through the superficial detritus between Bishop's Castle and Norbury. I need not here repeat, that there is not the slightest chance of ever finding coal in the Silurian rocks, and therefore to penetrate gravel, merely to reach such rocks, is indeed labour thrown away. (See pp. 328, 411 and 488.)

[2] The course of the Camlet through the fissure of Marrington Dingle, in a direction precisely the reverse of the ancient lines of drainage, is a very striking proof of how this stream has taken advantage of one of the *last formed* rents and depressions by which the surface has been modified. In following the thickly wooded banks of this little stream from Church Stoke to the north-west, the traveller, who merely hears the gurgling of the water, is impressed with the belief that he is *ascending* to its source, while in reality he is *descending* towards its mouth. This deception is produced by the partial rise of the hills towards the north-west, though the bottom of the valley really *deepens* in that direction. This added to the known fact, that the great drainage of

and is forced to pass round the southern extremity of the Long Mountain, before it can unite with the Severn near Welsh Pool. The fact of this sluggish stream, thus feebly wandering, at a very slight inclination, in a country considerably above the sea, points out that a change of level, of a few feet only, must have drained the whole of the adjacent low countries from a cover of water; and this view is supported by the fine character of the debris in the Vale of Montgomery, it being very distinct from that of the coarse detritus which has been thrown off the flanks of the adjacent volcanic region of the Cornden Hills.

Sufficient evidence has now, I hope, been produced to satisfy the reader;—1st. That the largest accumulations of gravel throughout this region were formed beneath the sea. 2ndly. That after the earliest desiccation of the submarine surface, the newly raised land was, for a long time, in an intermediate state, and in a great measure watered by lakes and broad rivers. 3rdly. That in consequence of successive upheavings of the land, the transverse gorges and fissures have been deepened, by which large volumes of water have been let off; and, lastly, that the sea being further removed by each movement of elevation, former estuaries were desiccated, previous strings of lakes reduced to the mere rivers of our day, and the direction of some of the early river courses changed. This view will be further illustrated and sustained by a consideration of the remains of extinct species of quadrupeds which are found in the gravel and in clefts and caverns.

### *On the presence of the Bones of Quadrupeds of extinct species in Siluria.*

Among the various methods of establishing the early existence of dry land, none is more effective than the presence of the remains of terrestrial animals of species now extinct. If, as in the present case, such evidence be combined with that of the former existence of lakes, their desiccation, the subsequent deepening of river beds, and the formation of river shingle and gravel during long periods, the proofs are complete[1].

the region is to the south-east, has led the country people to say that "the Camlet is the only river in Shropshire which runs up hill."

[1] A good example of caves, containing bones of extinct quadrupeds in North Wales, was pointed out by the Rev. Edward Stanley, now Bishop of Norwich. (See Proceedings of the Geological Society, vol. 1. p. 402.) These caves occur in the carboniferous limestone of Cefn, in Denbighshire, at a height of about 100 feet above the present drainage of the country. The remains consist of a humerus of a *Rhinoceros*, a tooth of a *Hyæna*, and other fragments, and they were covered by and immersed in calcareous loam, containing also a few angular fragments of limestone. Beneath them, and under what the author considered to be the floor of the cave, was another deposit, differing from that above, in containing also fragments of bones and rounded pebbles of old rocks. The evidence which has yet been produced appears to me scarcely adequate to sustain the inference that the cave was *inhabited*, though it affords satisfactory proof that such wild animals then existed in an adjacent region. It may be objected, that as gravel containing recent species of sea shells (the northern drift) has been found upon the high ground above the cave, that this district may have been inundated by a marine drift, after

Till very recently there was no good evidence of the remains of extinct quadrupeds in Siluria. This may be attributed to the country having been little explored; for as the bones of such animals had been found, near Worcester, in gravel partly derived from the rocks of this region, there could be little doubt that places of accidental sepulture would eventually be detected. Such has proved to be the case. Dr. Lloyd, of Ludlow, recently communicated to me the discovery of a large accumulation in a cleft of the Ludlow formation at Alden, near the View Edge, and during the last summer I accompanied him to the spot. The bones in question occur in fissures of the Aymestry limestone, which are nothing more or less than the vertical joints of that rock, irregularly opened out by ancient disturbance of the beds[1]. (See p. 243.) These jointed rocks form the eastern side of a deep comb, the higher parts of which are occupied by the Upper Ludlow Rock, the lower by the Aymestry limestone, which, where it contains the bones, is about 40 feet above the little brook that waters the valley. In extracting the limestone for use, these fissures were perceived to be filled with calcareo-argillaceous cement of a whitish colour, like hardened mortar, in which remains of animals have been, from time to time, detected, including stags' horns and bones of great size. In clearing away the limestone a large part of the principal fissure has been obliterated, and most of the bones first discovered have been lost. Through the zeal, however, of Dr. Lloyd and Mr. Duppa Lloyd, other remains have recently been collected, which sufficiently prove the character of the accumulation; for not only have bones of *deer* and *ox* been found, but also a perfect tooth of a *hyæna*, and the femur of a *rhinoceros*, together with several small bones which have not been determined. I will not here enter further into the difficult question of how these bones can have been lodged in such quantities in par-

it was dry land. So far from seeing any reason to adopt this view, the evidence would lead me to a directly opposite conclusion; for even if the cave were proved to have been inhabited, there can be no doubt that its tenancy took place *after* the elevation of the bottom of *the sea* containing the northern drift. All the physical features agree with this view. They lead us to suppose, that the Vale of Cyffredan, over which the caves impend, was one of those deep inequalities formed during the period when the whole tract was submarine; and that when the bottom of the sea was elevated, this vale might for a long time have been left in the condition of a lake, the waters of which first reaching to the level of the caves might have been afterwards let off by the opening out of the gorges, and the gradual lowering of the water courses, in the same manner as we have described throughout Siluria. In this way, the coarse gravel at the bottom of the cave may have been either the residue of part of a previous drift, when the tract was submarine, or deposited by a subsiding lake; while the calcareous loam in which the bones are imbedded, may have simply resulted from the disintegration of the rocks on the side of the fissures leading to this cavern, and by the action of atmospheric causes.

If the Cefn caves were situated within the Silurian region, I should have entered at greater length into their description, explaining them by a wood-cut, taken from one of the beautiful sketches with which Mrs. Stanley illustrated the memoir of the Bishop of Norwich.

[1] In speaking of the position of the beds it should be stated that they dip into the valley at a slight angle, and hence may have been moved in the manner formerly described (p. 248.). From the position, however, and different inclination of the strata on its opposite sides, it is evident that this comb has been affected by some of the great dislocations which resulted from the heaving up of the Ludlow and adjacent promontories.

ticular clefts of the rock[1], but I pass on with the remark, that this example in the very heart of Siluria, is all that can be desired to prove, that like other parts of England, this tract was inhabited by wild animals whose species are now extinct[2]. I would further observe, that there are also true caverns, in which the remains of *extinct* animals may probably hereafter be found, such as Ippikin's Rock[3], in Wenlock Edge (p. 212.), the great cavern of the Nash Scar Limestone, near Presteign (p. 314 and note).

That quadrupeds of extinct species inhabited this region, is further proved by the contents of certain gravel heaps on its eastern limits. In a pit south of Eastnor Castle, where the fragments consist exclusively of Silurian rocks and syenite of the adjacent hills, the remains of the elephant and other animals have been found; and at Fleet's Bank, near Sandlin, the bones of the rhinoceros and ox[4]. The first-mentioned locality is in the midst of a Silurian group of rocks, the other at the foot of the eastern slope of the Caradoc sandstone of Old Storridge Hill, and about 50 feet above a little stream. At both places the gravel is *exclusively* derived from rocks in the immediate vicinity; and as neither deposit contains a fragment of far transported rock, we have a right to infer, that certain extinct species of elephant, rhinoceros, ox, and deer, formerly ranged over Siluria. The bones of the same animals are also found at Powick, Bromwich Hill, and other places near the town of Worcester, amid similar local detritus, mixed with a considerable proportion of the northern drift, together with the sea shells of existing species to which we have before alluded. There can, consequently, be little doubt that while Siluria, as before inferred, was above the sea, and a portion of the valley of the Severn was under it, the adjacent lands were inhabited by quadrupeds of extinct species, *whose* remains have in some cases been preserved in purely local, fluviatile and lacustrine deposits, and in others were the marine accumulations of the strait or estuary into which they had been drifted.

### *Remains of extinct species of Quadrupeds in ancient fluviatile deposits.*

Having shown that the western shore of the submarine tract of the Vale of Worcester was formed by the Abberley and Malvern Hills, we have now to offer still more convincing proofs of the existence of land upon the east, by pointing out a local drift,

[1] See Dr. Buckland's ingenious explanation of such collections of bones, Reliq. Diluv. p. 56., and Bridgew. Treat. vol. i. p. 94.; De la Beche's Geol. Man. p. 201, &c.

[2] The Rev. T. T. Lewis procured the femur of a stag from the gravel of Leominster.

[3] My young friend Mr. Evans, of Kingsland, partially examined, at my request, the cavern at Ippikin's Rock; but although he found in it layers of alluvial deposit, he did not detect organic remains. He was, however, unprovided with sufficient assistance to make that thorough examination, which will I trust be completed, through the labours of the Ludlow Natural History Society, the nearest scientific body to the spot in question.

[4] The latter were found by Mr. J. Allies, who has also collected the bones of the horse, rhinoceros, elephant, &c. at Powick, and those of a rhinoceros at Bromwich Hill, near Worcester.

which having proceeded from the E.N.E., is exclusively charged with terrestrial and fluviatile remains.

Mr. H. E. Strickland is the discoverer of these ancient fluviatile deposits, which extend from Warwickshire into the valley of the Severn, near Tewkesbury. He has found the remains of twenty-four species of fluviatile shells, three of which are considered to be extinct, and the bones of several species of extinct quadrupeds in the gravel of the valley of the Avon, an eastern tributary of the Severn. (See Geol. Proc. v. ii. p. 111.) Let us now see whether this phenomenon be reconcileable with the view here given, of the comparatively recent period at which the valley of the Severn is supposed to have lain under the sea. The accumulations at and near Cropthorn constitute terrace-like hillocks, from one to four miles distant from the present bed of the Avon, above which their summits rise to a height of forty to fifty feet. Mr. Strickland has traced these accumulations, which he first termed "fluviatile diluvium," at intervals from Lawford in Warwickshire, to Defford in Worcestershire, and he has proved that they follow more or less the course of the present Avon from north-east to south-west. I refer to his interesting paper, shortly I hope to be published at length, for the details presented at different localities, it being sufficient for the present purpose to state the general results[1].

[1] The following is a list of the shells found here. v. r. denotes very rare; r. rare; c. common.

Terrestrial.

| | | |
|---|---|---|
| 1. | *Helix virgata* | v. r. |
| 2. | —— *pulchella* | r. |
| 3. | *Pupa marginata* | r. |
| 4. | —— *pygmæa* | v. r. |
| 5. | *Succinea amphibia* | r. |

Aquatic.

| | | |
|---|---|---|
| 6. | *Lymnæa palustris* | v. r. |
| 7. | —— *fossaria* | r. |
| 8. | —— *peregra* | r. |
| 9. | —— *cunicularia* | v. r. |
| 10. | *Planorbis nautileus* | v. r. |
| 11. | *Planorbis vortex* | r. |

Aquatic.

| | | |
|---|---|---|
| 12. | *Planorbis complanatus* | r. |
| 13. | —— *lateralis* (Strickland) | c. |
| 14. | *Ancylus lacustris* | v. r. |
| 15. | —— *fluviatilis* | v. r. |
| 16. | *Valvata fontinalis* | c. |
| 17. | *Paludina tentaculata* | c. |
| 18. | *Paludina minuta* (Strickland) | r. |
| 19. | *Cyclas Henslowana* | c. |
| 20. | —— *amnica* | c. |
| 21. | —— *cornea* | c. |
| 22. | *Anodon anatinus* | c. |
| 23. | *Unio ovalis* (Fleming) | c. |
| 24. | —— *antiquior* (Strickland) | r. |

The valves of a *Cypris* also occur.

The *Paludina minuta, Planorbis lateralis,* and *Unio antiquior,* appearing to be extinct species, have been named and described by Mr. Strickland: all the others are existing and indigenous to Britain.

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The bones which occurred here belong to the following animals:

1. Hippopotamus.
2. Bos Urus.
3. Cervus.
4. Canis.
5. Ursus.

All of extinct species.

The parts of these accumulations which Mr. Strickland has traced for many miles into the upper parts of Warwickshire must doubtlessly have been of purely fluviatile origin.

I examined in company with him two of the sections to which he refers. The clearest of these is at Bricklehampton Bank, near Cropthorn on the Avon, where about 20 feet of this detrital matter is arranged in the following manner resting upon the lias clay.

*Upper portion*, stiff reddish clay with a few pebbles; the *central* also argillaceous but more marly, of green and purple colours, with some yellow sand and occasional irregular laminæ of marl; *lowest*, sand and gravel confusedly mixed up with lumps of marl, pebbles of quartz (some 5 to 6 inches in diameter), broken chalk flints, much detritus of the lias, and very rarely a fragment of oolite.

Many of the delicate shells mentioned in Mr. Strickland's list, were found from the top to the bottom of this varied, and almost coarse drift; being just as abundant in the underlying gravel as in the overlying marl and clay. The bones of the quadrupeds occurred also through the mass, though they were most abundant in the lower part. The discovery of these fragile shells, perfectly preserved in beds of such coarse and irregularly formed detritus, is of importance, as it proves that much of the gravel to which the term "*diluvium*" has been applied, may have been deposited by rivers.

It is thus evident, that these fluviatile materials were drifted by a river which flowed through dry land on the E.N.E. into the channel or estuary so often mentioned; and it is therefore probable, that they were sometimes transported beyond the mouth of the ancient Avon, and deposited in shoals or banks beneath the waters of the channel.

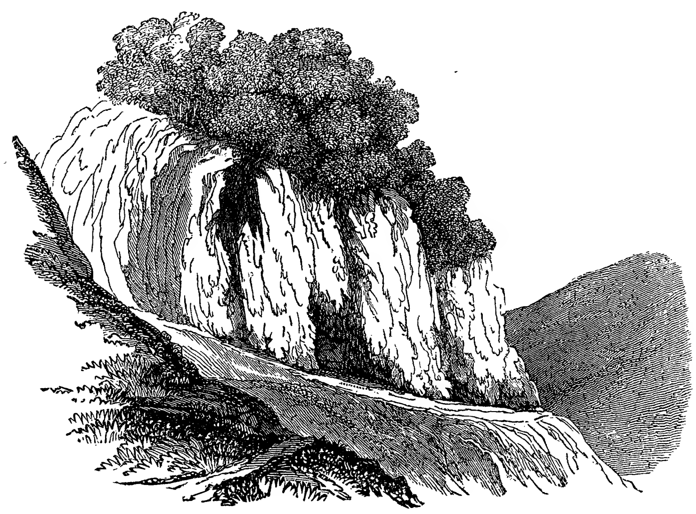
The bones of extinct quadrupeds, already noticed as occurring on the western or opposite side of the valley of the Severn, at Powick and Bromwich Hill near Worcester, and at Fleet Bank near Sandlin[1], were probably at once washed into the ancient estuary from the adjoining hills by sudden and local floods, as they are not imbedded in debris similar to that of the Avon. The physical features of the country marked by the narrow ridge of the Malverns impending over the valley, account, indeed, for the non-existence of former rivers, and consequently of fluviatile shells in this direction.

But were all these extinct terrestrial remains deposited in gravel when the marine shells were living in the sea? In answering this question it might be argued, that the great mass of the fluviatile and land shells are of existing species, and that the few which are supposed to be lost, may possibly still exist and have escaped the research of naturalists. On the other hand it might be said, though all the marine shells we have yet discovered associated with northern drift, appear to belong to existing species, other shells may yet be found which are extinct. The sea shells of the marine drift, and the fluviatile shells of the Cropthorn gravel, *may* therefore have coexisted. But are we to explain this Avon deposit by the hypothesis of pure fluviatile action, after the bed of the adjacent straits had been partially raised, or shall we suppose that the marine gravel on the adjoining hillocks, formed the shallow subaqueous banks of an estuary through which the mouth of the Avon then found its way to the sea? Adopting the first of these

[1] Through the kindness of the members of the Worcestershire Natural History Society, I procured a large suite of the animal remains found in these localities, and submitted it to Mr. Clift, Curator of the Museums of the Royal College of Surgeons, who informs me, that the bones belong to extinct species of hippopotamus, rhinoceros, elephant, stag and ox.

hypotheses, Mr. Strickland supposes, that after those parts of Worcestershire and Warwickshire before described had been long under the sea, an elevation of some hundred feet converted them into dry land, and that a river or chain of lakes then descending from the north-east, re-arranged much of the desiccated gravel of the northern drift, disposing it in thin strata, and imbedding in it the shells of mollusks and the bones of quadrupeds. This river, it is presumed, may have extended as far as Tewkesbury, and there emptied itself into the marine strait, which Mr. Strickland, agreeing with me, believes to have then occupied the lowest portion of the Vale of Worcester. A final elevation of the land to the amount of 60 or 80 feet is presumed to have reduced the Bristol Channel to its present form; and by this rise the fall between Warwickshire and the sea being increased, the Avon is supposed to have acquired a velocity adequate to carve out its bed to the present level, leaving its ancient detritus at heights of from 30 to 40 feet above the present stream. Although I at first held an opinion somewhat different, founded upon the apparent higher antiquity of the quadrupeds whose remains are imbedded in the Avon deposit, I am now convinced that the fluviatile hypothesis suggested by Mr. Strickland (the same as that by which Mr. Lyell accounts for the formation of the "loess" of the Rhine,) explains naturally and simply the relations of the terrestrial and fluviatile deposits of the Avon to the marine gravel.

Interesting as these conclusions are, it would be wrong to generalize from the facts on which they are based, by supposing that bones of extinct quadrupeds are only to be found in association with terrestrial and fresh-water remains. For although as a necessary result of the early configuration of the land, such collocations must have frequently occurred, many of the examples of the so-called diluvial accumulations, doubtless originally washed down by rivers, must, as above stated, have been often drifted far beyond their mouths to form deltas *under the sea*. In this way only can we satisfactorily account for the presence of the remains of extinct quadrupeds in the gravel of other parts of our island, associated as they often are with marine shells of existing species.





*Modern Travertine of the "Southstone Rock," Worcestershire, from a drawing by Mrs. Murchison.*

# CHAPTER XLI.

## SUPERFICIAL ACCUMULATIONS (*concluded*).

Terrestrial changes within the modern æra. *Desiccation of lakes and turbaries.—Modern action of rivers.—Accumulations of blown sand.—Exposure of submerged forests.—Formation of shell marl and travertine.*

### *Desiccation of Lakes and Turbaries.*

IN the previous chapter it has been explained how certain lakes may have been drained during periods antecedent to our records, though some of these bodies of water, as the Wigmore Lake, appear to have been desiccated within the range of tradition. We shall now treat exclusively of those operations which are entirely modern. It has been shown, that the highest land occupied by the marine gravel, containing sea shells of existing species, ranges from Marrington Green, north-west of Shrewsbury, to Ashley Heath, in Staffordshire, and varies in height from 500 to 800 feet above the sea. From this culminating crest, the present streams descend northwards into the estuary of the Dee and Mersey, and southwards into that of the Severn. Now, as many of the minor streams which rise in this crest, had a long way to flow with only a slight descent, it necessarily happened, that in the early periods of our æra numerous lakes and stagnant pools were formed in a surface which was then intersected with irregular depressions. Some of

these cavities having been gradually filled with silt, have become turbaries, and others cultivated land.

The most superficial examination of North Salop and Cheshire affords abundant evidence of these modern operations, and shows that large tracts, formerly occupied by sheets of water, have been drained, and converted into turbaries and mosses resting upon sand and gravel. That many of these turbaries were anciently lakes, or marshy woodlands, is completely proved by their contents. In the great Whixall Moss, between Prees and Ellesmere, which is even now impassable in many parts, dogs having been there lost in the pursuit of game, are found vast numbers of prostrate oak, birch, and fir trees, with fir-cones, generally in good preservation[1].

Wherever the descent is adequate, these lakes, after having been marshy woodlands and mosses, have in many places been brought into cultivation. A good example of this process is seen between the towns of Wellington and Newport, and is known under the name of the "Wild or Weald Moors." I am indebted to Mr. T. Eyton for directing my attention to this district, and for pointing out to me a short account of it by the Rev. G. Plaxton, who was incumbent of the parish of Kinnardsey, in the year 1673. Much of the surface of the "*Wild Moors*," (now arable land) was then an impassable bog, and the author inferred, that at no distant period, the whole tract was a marsh, except those places which having the word "Ey" affixed to their names, appear to have been islands. Thus we have Eyton (or the town surrounded by water), Kinnardsey (Kinnard's Island). In proof of a large portion of this tract having once been a forest, afterwards a peat bog, Mr. Plaxton cites the existence of large trees at various spots, in which (as may be now observed in Ireland) the peat had shrunk and left them standing "as if on high stilts[2]," whilst he states that the fibrous and decomposed materials of which large portions of the surface were composed, exactly resembled that "sludge or refuse which floods would leave upon the ground." (Phil. Trans. 1707.)

Mr. Eyton, sen., pursues his conjectures further, and conceives that the "Wild Moors" were not merely marshes occasionally flooded, but in more remote periods were constantly covered by water. This he infers, 1. From the names of all the places in which the New Red Sandstone rises up as islands through the moory surface, containing the syllable "Ey" (water). 2ndly. From the point where the surface of the moors or supposed lakes decrease in breadth being called Long*ford*, indicating a communication between the opposite banks. 3rdly. From the adjoining town being called New*port*[3], implying a site to which the lake was once navigable, and to which

[1] The Rev. Thomas Egerton informs me, that this moss having been cut into to a depth of 40 feet near its edge, many of these trees were found, and that the bottom of the accumulation was white and grey sand.

[2] To any one acquainted with the bogs of Ireland such appearances are familiar. We may, indeed, account for the shoots of trees being found in peat, by supposing that when the lakes were drained, certain islets upon which trees grew, subsided during the general desiccation, and became merged in the bog.

[3] *Port* is sometimes used for *gate* (Scotland). Is the etymology in the text conclusive ?—R. I. M.

intercourse might have been carried on from the islands and adjoining country. This speculation is apparently confirmed by the composition of the peaty soil, and from its lying in a hollow upon gravel, supposed to have been the bottom of the ancient lake. It is further imagined, that, in former times, this lake discharged its waters into the river Tern, near Slean, and was converted into a peat bog by the bursting of a dam, near Longdon upon Tern, where considerable heaps of gravel attest the probability of such an operation. These tracts, after passing through a condition of bog or peat moss, were gradually consolidated, and then became a waste, which from ancient records, is known to have constituted part of the "Vasta Regalia," or Royal Forest[1], which included the Wrekin and the wild, or weald (woody) moors. In corroboration of these views it may be stated, that stags' horns (*Cervus Elaphus*) with freshwater shells and arrow heads, have frequently been found in the peat. These speculations and the data on which they are founded seem to afford a good explanation of the process by which many similar tracts in Lancashire, Cheshire, and the central counties may have been drained.

Whilst we thus trace the natural progress from lakes into bogs with forests, and from these into land in its actual state, we are entitled to speculate on a more ancient terrestrial condition, yet still subsequent to the last great elevations of the land from beneath the sea, when the fossil elk of Ireland and other gigantic animals of lost species were in existence; for although we have not yet heard of these remains being found in Shropshire (where after all little search has been made to detect them), it is certain that such have been discovered in the low parts of Lancashire, &c., tracts which we have shown to have been laid dry at the same period with those the nature of which we have been considering[2].

If the careful examination of such districts conducts the historical inquirer back to the period immediately preceding the present, the geologist easily transports himself to remoter conditions of dry land, when the *mammoth*, *hippopotamus*, *rhinoceros*, *hyæna*, and other wild animals of species now extinct, inhabited the regions, which were then dry.

——— "cumque
Rara per ignotos errent animalia montes."

Tracing the inquiry still further back, he discovers in the newer tertiary deposits, but formed long anterior to our æra, the remains of mammalia still more distinct from those of our own epoch, such as the Mastodon, and proves a yet more ancient condition of

[1] Sir Humphrey de Eyton was ranger of this forest in 1390.

[2] It has been stated that portions of the Gigantic Elk, *Cervus giganteus* (Cuvier), have been found in the gravel in the low flat of Awre, near Purton Passage, where the Severn is fast passing into an estuary. I am not aware that this is correct, for in a list of remains found in this alluvium given by the Rev. C. Pleydell, Quarterly Journal of Science, January, 1830; the animal remains, with the exception of fossils of lias and adjacent rocks, would appear to belong to existing species of deer, horse, hog, &c.

things. Again receding to a remoter period, he detects in the bones of singular creatures, somewhat analogous to, though very different from the modern *tapir*, named by Cuvier, *Palæotheria* and *Anoplotheria*, undoubted proofs of dry land and lacustrine accumulations; and thus our science enables us to take an analytical view of bygone periods, each æra being distinctly characterized by the monuments which it has left for our examination.

*Modern action of rivers.*—Although on a much smaller scale than in more mountainous countries where streams descend rapidly to the plains, there are several good examples in this region of the erosive fluviatile process, showing, 1st. That where the rivers descend from high grounds they have worn their way through pre-existing shingle banks of an earlier period. 2ndly. That though the rivers have *not formed* the gorges through which they pass, yet they have partially *deepened* their beds by the attrition of the materials which they have hurried on. 3rdly. That they have formed deltas both along their course and at their mouths.

If, however, we observe the feeble efforts which all the Silurian rivers now make in their passage through the plains, and see that they there merely re-arrange a few materials distributed by former action of water, and occasionally make slight changes in their beds, we shall have a firm conviction, that their present volumes of water would have been perfectly inadequate to excavate the deep hollows through which they occasionally flow. A good example of ordinary fluviatile action is seen in the wide river plain of the Towy, below the town of Llandovery, where the river has so changed its course amid the wreck of the former detritus, that it now flows half a mile from Llandegjad Church, though it formerly passed close by the building. On the other hand, the Sowdde, a tributary of the Towy, is an excellent example of a stream still highly active. This river, descending from the lofty fans of Caermarthen, hurls down in extraordinary floods bowlders of Old Red Sandstone and coal grits, 2 to 3 feet in diameter, and distributes them with much red mud over an arid flat near the town of Llangadock[1], where the Sowdde unites with the Towy. But the Sowdde does not break these bowlders from the parent rock. The deep upland valley through which it flows, extending from the base of the Caermarthen Fans by Gwinfe to Castel Cerrig Cennen, and immediately beneath the most elevated and broken portion of the margin of the coal-field, is covered with considerable quantities of coarse detritus accumulated as before described by ancient submarine action, and the river Sowdde rushing down through these heaps merely transports the ready-made blocks to the vale at Llangadock[2].

[1] After each flood the Sowdde leaves also a broad superficial deposit of red mud, and when the river is highly saturated with this detritus, the waters of the Towy into which it falls, are discoloured, even to the neighbourhood of Caermarthen.

[2] Other analogous examples of torrential river action might be cited from the precipitous escarpments of the South Welsh coal-field; for example, the streams descending into the Vale of the Usk, south of Crickhowel, and that at Pontypool quoted by Dr. Buckland, Geol. Trans., Old Series, vol. v. p. 531.

Enough has now been stated to show, that in this region, the present erosive action of water upon *hard* rocks is confined to the mountain tracts. At the same time, it must be recollected, that our Silurian rivers, even after they quit the mountains, though no longer employed in transporting stones and coarse gravel, are very active agents in carrying away a large proportion of the earth's surface in the form of sand and mud. No European river of equal magnitude is charged with a larger amount of turbid sediment than the Severn,—the result of its own long course (and of those of its tributaries) through tracts of mudstone, marl, and soft sandstone. Such rocks being easily decomposed and degraded, have afforded those finely levigated materials, a portion of which has added new lands on the banks of the river[1]; but by far the larger quantity has been borne away into the great estuary of our Island. The shoals there accumulated during past ages, and still depositing, may hereafter be examined, if other changes of the relative level of sea and land shall take place; and future geologists may then study the sub-aqueous formations of our own æra.

### *Blown Sands.—Submerged Forests, &c.*

Among the phenomena of modern date must be noticed blown sands and submerged forests. The former occur extensively on the coasts of Pembrokeshire and Caermarthenshire. Between St. David's and White Sand Bay they cover hills at heights of more than 150 feet above the strand, and are prolonged upwards of a mile inland among the slaty rocks. Again, at the mouths of the bays of Freshwater east and Freshwater west, as well as at points of the Stackpole promontory, are great heaps of this sand, which, in places, present escarpments 30 and 40 feet high. These sands contain a prodigious quantity of land shells, including *Helix aspersa, H. virgata, H. rufescens,* and *Bulimi* of 3 or 4 species. It might naturally be supposed, that these sands are still increasing; but such is not the case; for many of them appear to have been stationary during long periods. On the summit of the slaty coast cliffs at St. David's stands a ruined chapel, around which and far beyond it inland, much blown sand has been heaped up, while the sides and floor of the building are free from it. Again, at Newton Burrows a ridge of Old Red Sandstone is surmounted by a *cromlech* (half a mile distant from the shore), and yet this low erection, though environed by dunes of sand much higher than itself, has not been covered over. In Pembrokeshire, therefore, local causes, which were in action at remote periods, must have been discontinued, in one instance before the Druids erected their cromlech, and in the other before the monks built their chapel; and in neither case has the sand advanced beyond its *ancient* limit. The cessation of the action which formed these dunes is further proved by the form of the ground, for at Newton Burrows the sand is heaped up in spots *higher* than the

[1] See note 1, p. 450, in which the rapid formation of new land on the banks of the Severn is pointed out.

adjacent inland tract; and although every facility seems thus to be offered for the advance of the sand flood, we have proofs that it has made no progress from the earliest days of British history. In fact, it appears as if, having formerly been blown into comparatively lofty situations, the sand had there become consolidated and bound together at a particular period, probably in part by the growth of bent grass, and that it has since formed a natural barrier, sheltering the inland country from the force of the south-western gales.

The coast of Caermarthenshire, on the other hand, presents many examples of similar accumulations of sand which are daily increasing, and form low hills upon the strand. These, at certain distances from the main land, act as bars to the removal of the fine detritus brought down by the streams which at these points empty their contents into the sea. The most remarkable example of this natural process is at the mouth of the Taaf, below Laugharne in Caermarthenshire. That river, after a passage through soft shale or mudstone, deposits its fine sediment over a wide space, having a seaward barrier of sand banks. The accumulation thus formed, and within modern times, constitutes some of the richest land cultivated in South Wales, and the edges of the delta are continually augmenting. None of the dunes now forming, are, however, of the height and magnitude of those of comparatively remote date.

### *Submerged Forests.*

Another operation, and one most important in connection with geological theory, must be here alluded to—the change of relative level of land and sea. The cliffs of Pembrokeshire, which are so extensively and well exposed, offer, indeed, no evidence that this promontory or the mass of South Wales have undergone any sensible elevation or depression within the modern æra. Two examples, however, of submerged forests have come within my knowledge; but it is by no means certain that these phenomena have been caused by a lowering of the coast; for forests may have grown at very low levels, protected from the inroads of the sea by shingle banks, the removal of which would occasion their destruction by giving rise to a sudden influx of the sea. One of these submerged forests is occasionally seen on the shore at Gupton Burrows, in a low bay between the opposite promontories of Old Red Sandstone and carboniferous limestone. After powerful storms, the sands being washed away, a stratum of clay and peaty earth is exposed, through which the stumps of trees protrude, as if in a growing posture. The other case, precisely analogous, is on the shore of Newgale Sands, St. Bride's Bay, where, according to Giraldus Cambrensis, the forest was once exposed to a considerable extent. Relating his travels, the Archbishop observes:—

"We then passed over Niwegal Sands, at which place, during the winter that King Henry the Second spent in Ireland, as well as in almost all the *western* parts, a very remarkable circumstance occurred. The sandy shores of South Wales being laid bare by the extraordinary violence of a storm,

the surface of the earth, which had been covered for many ages, reappeared and discovered the trunks of trees cut off, standing in the very sea itself, the strokes of the hatchets appearing as if only made yesterday; the soil was very black, and the wood like ebony: by a wonderful revolution, the road for ships became impassable, and looked not like a shore but like a grove cut down (perhaps at the time of the deluge, or not long after), but certainly in very remote times, being by degrees covered and swallowed up by the violence of the seas. During the same tempest many sea-fish were driven, by the violence of the waves, upon dry land."—Itinerary of Archbishop Baldwin, 1588. Edition of Sir R. Colt Hoare, 1806. vol. 1. p. 217.

However these submarine forests may be accounted for, whether by a partial subsidence of the land, or irruption of the sea, no evidences have yet been discovered of the coasts having undergone any recent movements of elevation, there being an entire absence of those raised beaches full of modern sea shells, which occur around so many parts of the *English* shores. This is the more remarkable, since Professor Sedgwick and myself lately discovered examples of such elevation on the coast of North Devon, opposite South Pembroke. The apparent absence of *recent* elevation on the shores of South Wales is of high interest, in tending to strengthen the speculation which I have previously entertained, concerning the ancient hydrography of Siluria, when compared with that of England; the whole region to the east, north, and south of the Severn being supposed to have been elevated since the creation of existing species of *mollusca*, whilst the country through which we have traced the range of the Silurian and other ancient rocks having been previously raised from beneath the sea, has since remained in a comparatively quiescent state.

## *Marl Lakes.*

An accumulation of shell marl was recently discovered in Montgomeryshire, on an estate belonging to Lord Clive. It is situated about one mile south-west of the town of Montgomery, in a small hollow, bounded on the east by a ridge of flaglike Silurian rocks, and on the other sides by low hills covered with coarse gravel. This upland hollow is about 300 or 400 feet above the contiguous valley of the Severn. The soil being profitless and wet, the farmer in occupation resolved to drain it. Beneath the surface he found a bed of peat about four feet thick, and immediately under it, a stratum of fine, light grey marl, filled with delicate white shells, *Lymnæa ovalis* and other existing species. When I examined the place, a deep trench several hundred feet long had been cut, and the shell marl, which was about three feet thick, appeared to rest upon clay; but as the water rose to the lower edge of the marl, I could not ascertain satisfactorily the nature of the sub-soil. In a moist state, this marl, though very sandy, is easily cut into blocks, which, when dried, become perfectly white.

Theoretically, the position of this shell marl is very interesting. It has been deposited in a tract which contains no limestone, although a very minute quantity of calcareous matter is disseminated through some parts of the surrounding rocks. It is

possible that the lime which enabled the mollusca to form their shells, was supplied by calcareous springs, though it is more probable that the minute quantity required for the wants of fluviatile testacea, may have been afforded by the percolation of rain water through the surrounding rocks. Fully to comprehend the method in which such beds of shell marl have been formed, the reader must consult the writings of Mr. Lyell, who has so admirably described deposits of this nature in the lochs of Forfarshire, North Britain. (See Geol. Trans., 2nd series, vol. ii. p. 72.) The Montgomeryshire marl agrees with that of Forfar, in being covered by a thick stratum of black peat.

As this marl of Sutton is an excellent manure, and the surrounding country contains no limestone, its discovery is of considerable practical importance; for although the hollow in which it is deposited is small, analogy may fairly lead us to infer, that similar and larger basins of the same substance, may yet be discovered beneath the turbaries and mosses so numerous in the upland valleys of Montgomeryshire.

## *Travertine.*

We have now reached the last stage of our researches into the nature of the superficial deposits and have only to explain the production of those modern rocks, formed under the atmosphere, and to which the name of travertine has been applied. Such rocks have been deposited from the remotest periods of history to the present day, and in most countries. They are very abundant in districts which have been or still are subjected to volcanic action, as in the environs of the Tiber, whence their name of travertine[1]. They are, however, almost equally abundant in countries, where there are no distinct appearances of volcanic action near the surface. All that seems necessary for their production is, that a spring should hold in solution a sufficient quantity of carbonate of lime, which, upon the escape of the excess of carbonic acid gas into the atmosphere, deposits its earthy residuum, thus encrusting the sticks, leaves, shells, or any other object over which the water flows.

There are many such springs in different parts of the region laid down in the annexed map, but from the insignificance of their deposits, few are worthy of attention. The strongest of them issue from the central member of the Old Red System, which is chiefly composed of marls and cornstone (concretionary limestone). A good example occurs two miles north of Ludlow, on the property of Sir W. Boughton, Bart., where a brook forms large and solid masses on its sides. The most remarkable, however, of these deposits are in the deep dingles called Piper's Brook, Sapey Brook, and at Southstone Rock, on the right bank of the Teme, between Tenbury and Knightwick Bridge. In Piper's Brook it partially encrusts the sides of the stream, and is found in large masses rolled down its bed.

[1] "Lapis Tiburtinus."—Ital. Travertino; Eng. Travertine.

This modern rock, which from its light and porous structure is there called "Puff Stone," was formerly much used for building, and has occasionally been burnt for quick lime.

The mass of travertine, called the Southstone Rock, *vulgo* "Rotch," and which occurs in a picturesque dingle, midway between Piper's Brook and Sapey Brook, is by far the largest of these deposits. It is about 200 feet above the Teme, and beneath the impending escarpments of cornstone of the Old Red System. The surface of this rock extends over at least half an acre, and is covered by a house and garden. At the northern extremity it terminates in a bluff precipice from 50 to 60 feet high, faced with gigantic botryoidal stalactites which hang over the dingle; and the mass being full of cavities, some of the interior passages lead, by winding paths, from the base to the summit. (See vignette, head of the chapter.) This rock, the largest body of travertine hitherto observed in Great Britain[1], has been entirely deposited by a spring, which gushes out on the eastern side of the cornstone, about twenty paces above the little cottage, and daily forms a fresh incrustation upon the edges of plants and stones. The rill has been so long in action, that a mass of rock of its own creation now forces it round to the south, before it can turn northwards and fall into the adjoining rivulet. In this newer part of its course I perceived that bricks and parts of old buildings had become cemented into the deposit. No lithological difference, however, can be detected in the matrix of the rock forming its ancient and modern extremities, except that the former is perhaps rather more compact than the latter. Here, as well as in parts of Sapey Brook and Piper's Brook, it is associated with a cream-coloured calcareous sand, sometimes very marly and unctuous. The only shell which I could perceive is the common *Helix nemoralis*, but it occurs in great quantities, associated with numberless fibres, and small stems of plants, grasses, &c. The road to the cottage, or eastern side of the rock, has been cut through about 15 feet of the travertine, which there rests upon the Old Red Sandstone.

The Southstone rock is a valuable landmark in proving the tranquillity of the surface of this district during the modern period. All the external features of the environs harmonize with this supposition, the adjoining valley of the Teme being filled only with the finely levigated fluviatile or lacustrine shingle, to which we have before

[1] "Extensive use was formerly made of travertine in this country, and it is still seen in old ecclesiastical buildings in Shropshire and Herefordshire. The ancient church of Quatford, near Bridgnorth, built in the 11th century, was altogether constructed of travertine. The nave was taken down many years since, but there still remains the chancel and a Norman arch, which are composed of it. Traces of it are seen in the eastern end of Quat Church, and it has been found in the middle of the church wall at Worfield, Chetton, and other places in that neighbourhood. In the walls of the chancel and other parts of Aymestry Church are regular courses composed of travertine, but they are evidently the worked up materials of a more ancient fabric, which was probably altogether composed of it; and a few blocks are seen likewise in the exterior walls of the eastern end of Wigmore Church." (Extract from a Letter of the Rev. T. T. Lewis.)

adverted. We hardly know how to institute comparisons by which to estimate the antiquity of this rock, so modern as respects geological monuments; and yet perhaps of such high antiquity in relation to man. It would not, however, be presumptuous to affirm, that the spring which formed it, has deposited similar matter without interruption, ever since the sub-strata were first exposed to the atmosphere; and far back, truly, must we recede to account for the commencement of this massive production [1].

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Having now conducted my reader from far remote periods, to the formations of our own days, I may terminate the history of the descriptive geology of this region, by reviewing the ancient dislocations by which it has been affected, and by considering briefly the origin and changes of the sedimentary deposits.

The second and concluding part of the work is exclusively devoted to the description of the organic remains of the Old Red and Silurian Systems, prefaced by a general view of the distribution of animal life during those ancient epochs.

[1] The Southstone Rock is thus described by Nash: "About a mile south of the site of the old church is an old hermitage raised on a steep ascent in the bosom of great hills; within the rock are some rooms hewn out of the hard stone; on the top of it was a chapel dedicated to St. John Baptist, on the feast of whose nativity here was a solemn offering; which ended, the assembly ascended by stairs cut out of the rock into the little chapel, where finishing their devotion they usually drank of a pleasant well, the water of which was famous for curing many disorders."—History of Worcestershire, vol. ii. p. 360.

# CHAPTER XLII.

## CONCLUSION OF PART I.—GENERAL VIEW OF THE FORMER CHANGES OF THE SURFACE.

*Parallelism and divergence of mountain chains.—Ancient dislocations, and their intensity.—Vastness of scale of former depository action.—Central heat.—Ancient dislocations and modern changes reconciled.*

IT has been repeatedly explained in the preceding chapters, and a mere glance over the accompanying map will show, that the prevalent direction of the stratified deposits in Wales and the adjoining borders of England, is from north-east to south-west. The map further shows, that this direction is coincident with the lines of fissure along which the rocks of igneous origin have been erupted; and thus we connect the effect with a cause, and make it probable that volcanic matter, bursting out in that allinement, has been instrumental in producing the leading direction of the strata.

This strike prevails throughout all the rocks of the Cambrian and Silurian systems, from Lilleshall and Haughmond Hills in Shropshire, to the mouth of the Towy in Caermarthenshire, a distance of upwards of one hundred and twenty miles. Even in Pembrokeshire, where, after many violent dislocations, the formations are partially cast into an east and west direction, as explained in the 28th and 29th chapters, the south-westerly course of the Cambrian and Silurian rocks is maintained in the coast cliffs of St. David's and in Marloes Bay, more than one hundred and fifty miles distant from their types in Shropshire.

When, however, we examine these phenomena more in detail, we find, that although there is a *general* coincidence in direction between each ridge of stratified deposits and that of the intrusive rocks, connected with or adjacent to it, the same direction does not always prevail in the separate chains at certain distances from each other. In the tract selected as the type of the Silurian System, the strike is true north-east and south-west, or parallel to the ridges of the Wrekin and Caradoc, and the same is on the whole persistent into Caermarthenshire; but, in the country situated to the west and north-west of the mineral axis of Shropshire, where the Silurian deposits undulate between the Cambrian Rocks of the Longmynd and the Berwyn mountains, there are marked discrepancies in the direction of the strata. Thus, in the singular mining tract of Shelve and Cornden, the lines of trap, and the stratified rocks trend N.N.E. and S.S.W.; in the

Long Mountain and Breidden Hills E.N.E. and W.S.W.; and in the country west of Welsh Pool north-east and south-west. Hence it appears, that in a zone not exceeding thirty miles in width, ridges composed of the same materials, and inclosing the same organic remains, have been elevated upon lines, which, so far from being parallel, would actually meet, if prolonged for a few miles. (See Chapter 21. p. 267.)

Should it, however, be conceded, that along the Welsh frontiers, the aberrations from what may be called parallelism are not very numerous, what shall we say of those Silurian Rocks which occur on the eastern side of Herefordshire, and in the central English counties? The axis of their elevation in the Abberley and Malvern Hills is from north to south, sometimes even N.N.W. and S.S.E., with a partial exception near Ledbury. The same rocks in the district to the north of Dudley, together with the coal and overlying deposits, have, it is true, been thrown into the old north-east and south-west direction, in the range extending by Wallsall; but the very same deposits, where affected by the great outburst of the Rowley trap, strike from N.N.W. to S.S.E. The last direction is parallel to the volcanic range of the Clent and Lickey Hills, which occupies in part the place of the Lower New Red Sandstone; while close at hand, and on the same parallel, trap rock of precisely similar character is detected, which at a much earlier period must have served as the elevating nucleus of the Lower Lickey, and which before the formation of the coal measures, had converted the Caradoc sandstone into the well-known quartz rock of that curious, miniature mountain. On the other hand, elevations have taken place along the same parallel, or rather radiating from the southern end of the Lickey, subsequent even to the accumulation of the red marl and lias, as proved by the line of dislocation affecting those deposits, which producing the Ridge Way, have caused the great longitudinal faults of Craycombe and Evesham, and left several patches of lias in Warwickshire in isolated positions. (See Map.)

The forces which impressed this direction from N.N.W. to S.S.E. upon the rocks of Worcestershire and Warwickshire, have also operated through a large tract of Leicestershire; for the Cambrian System of Charnwood Forest has a single anticlinal, which strikes from N.N.W. to S.S.E.; and the axis of the adjacent coal-field of Nuneaton has a similar direction; and hence we learn that this tract belongs to the same system of dislocation as the Rowley and Lickey Hills[1].

Again, though the major axis of the Silurian group at Usk is from N.N.E. to S.S.W., this agreement with the Welsh strike is more than counterbalanced by the remarkable anticlinal, proceeding from the Tortworth district on the *S.S.E.*, and terminating in the valley of elevation of Woolhope on the *N.N.W.* Here we have an axis of not less

[1] Professor Sedgwick, who has recently determined these interesting points concerning Charnwood Forest and Nuneaton, further informs me, that the principal movements must have taken place *after* the Lower New Red Sandstone was, at least partially, deposited, the phenomena thus agreeing with those described around Dudley. (See Chapters 35 and 36.)

than thirty miles in length, parallel to the elevations of the Rowley, Lickey and Charwood Hills, and specially affecting the Silurian System, and yet at right angles to the direction of many masses of that system elsewhere.

With such conflicting evidences, are we not led to infer, that it is impracticable to define the period of any given line of elevation merely by its direction? I am most unwilling to have the appearance of rejecting too hastily, and from phenomena which extend over a small portion of the surface of the globe only, that part of the ingenious theory of one of the most distinguished geologists of the present day[1], which implies that deposits of the same age have been elevated upon lines more or less parallel. Entirely to reject this proposition would be to assert, that volcanic matter had never burst out on parallel lines of fissure during the same periods of eruption, which is contrary to the experience of geologists and to many facts contained in this volume. No one, indeed, can have observed the linear direction of volcanic outbursts along sea coasts, and habitual vents of eruption[2], without acknowledging, that in accordance with modern analogies, ancient parallel fissures of eruption must often be found affecting deposits of the same age. But to whatever extent and under whatever limitations this branch of the theory of M. Elie de Beaumont may be received, the facts related in the preceding pages compel me to dissent from that part of it, which implies, that deposits of a *different* age have necessarily been thrown up in *divergent* directions; since it has been demonstrated, that accumulations of very different ages have been elevated during several successive ages upon the very same parallel. Thus, for example, the chief fractures and the major axis of the coal-field of Coal Brook Dale, as well as the striking dislocations on its margin, which affect the New Red Sandstone as well as the coal measures, are all coincident with the great north-east and south-west movement by which the adjacent rocks of the Silurian and the Cambrian System have been elevated; nay, more, the ends of the very ridges, cited as the types of the Silurian System, are prolonged into the heart of this coal-field, and thus the forces which elevated the former have given the same direction to the latter; though the Silurian strata were set on edge anterior to the deposition of the coal measures. The same phenomena are repeated in the Dudley and Tortworth tracts, though on another line of dislocation common to them both.

It has also been shown, that upon the direct prolongation of the axis of the Breidden Hills, trending from W.S.W. to E.N.E., eruptions of igneous matter have been renewed, at intervals, upon the same line of fissure, from the period of the Silurian System till after the formation of the lias, as proved by a line of fissure extending from the borders of Montgomeryshire through Shropshire into Staffordshire; while the very same deposits, i. e. rocks of ages as widely removed from each other as the Caradoc sandstone and the lias, on the line of the Rowley, Clent, and Lickey Hills, have been

[1] M. Elie de Beaumont. See also the views of M. Boué.

[2] See Scrope on Volcanoes.

affected by igneous eruptions trending in close parallels from *N.N.W.* to *S.S.E.*, a direction even at right angles to the contemporaneous line of fissure of the Breidden.

Thus, therefore, while we are taught, that volcanic action has taken place upon one and the same line of fissure during an immense succession of ages, producing lines of local parallelism between deposits formed at widely distant epochs from each other, we see that eruptions affecting the same deposits, have sometimes thrown the masses so affected into chains having a direction completely divergent from, nay, even at right angles to, each other.

If we restrict our inquiry to the carboniferous system, in vain shall we attempt to find any one direction more prevalent than another. The axis of the Glamorganshire, Caermarthenshire, and Pembrokeshire coal-fields, or great coal-tract of South Wales, is from east and by south, to west and by north[1]; that of Wolverhampton from north-east to south-west, those of Dudley, Lickey and Nuneaton from N.N.W. to S.S.E., that of Coal Brook Dale from north-east to south-west. The strike of the beds in the field of Shrewsbury is as various as the form of the promontories of the older rocks on which they repose. In the Denbigh and Oswestry fields the range is north to south; in that of Bewdley Forest, and in the Titterstone Clee Hill north-east to south-west. The last-mentioned district is an excellent test, since it is contiguous to the prevalent line of fissure in the Silurian System, and again, like the field of Coal Brook Dale, it has been *equally* affected with the older rocks, by the north-easterly strike; the eruptive channel of basalt by which this carboniferous tract has been penetrated being precisely parallel to the axes of elevation of the ridges of Caradoc, Wenlock, and Ludlow. In fine, the north-easterly and south-westerly direction so prevalent in Wales and the Welsh borders, being also apparent throughout many of the superior secondary formations of England, may, by some persons, be considered to indicate simply the outline of the ancient shores of this island, along which the deposits have been accumulated; and in accordance with modern analogies it might be inferred, that volcanic action or elevatory movements were renewed at intervals throughout many ages, upon fissures more or less parallel to such lines of coast.

Abandoning, however, this speculation, and confining our attention to the evidence before us, we are constrained to believe, that although igneous rocks have been ejected after long intervals, sometimes upon the very *same* lines of fissure, occasionally alter-

[1] The major axis of the great coal-field of South Wales, ranging from east and by south to west and by north, for so great a distance as one hundred miles, and of date so clearly posterior to the old axis of the North Welsh and Silurian mountains is, perhaps, the best example in England whereon to sustain that portion of the theory of M. de Beaumont which implies that chains having divergent directions were elevated at distinct periods. (See p. 406.) I may here add that, in common with all those geologists who have laboured in the field, I entertain a high respect for the talents and genius of M. Elie de Beaumont, who is one of the most enlightened modern observers; and even those parts of his theory to which I cannot subscribe, have been of great service to geologists, in pointing the way to researches and comparisons which might never have been attempted without the guidance of his general views.

nating conformably with the strata which were forming, but more often breaking in upon such accumulations subsequent to their consolidation, we must not forget that the younger deposits in this region are comparatively exempted from these signs of igneous outbursts. Within the whole area of the annexed map, there is not a single case of trap in contact with the lias, and only one of a dyke of that matter, cutting through the New Red Sandstone, whilst we have many proofs of volcanic action in the carboniferous strata (affecting also partially the Lower New Red Sandstone), a few evidences only in the Old Red Sandstone, and again, a multitude of eruptions amid the Lower Silurian and Cambrian Systems. It would appear as if, during the ancient periods of submarine accumulation, *this region* had been periodically much subjected to volcanic action, which, though repeated in subsequent epochs, diminished in the intensity and frequency of its outbursts after the carboniferous æra. This observation, deduced from practical knowledge of the structure of a given tract of country, may indeed be extended to nearly the whole of England, in which there are no traces of trap rock having been intruded into the strata posterior to the period of the oolite, though in Scotland the same action has been most rife *subsequent* to the formation of the oolites, and in Ireland after the consolidation of the chalk.

These geological phenomena are strictly in unison with modern observation, which has taught us, that igneous action is often discontinued for long periods in one part of the earth, and called into play in another. We are not, however, to suppose, that when volcanic matter ceased to be protruded, volcanic *action* ceased to operate, for since then, as we have shown, all the younger secondary and tertiary deposits have been dislocated and upheaved from beneath the sea. The forces which accomplished these great results were, therefore, we suppose the same, as those which evolved the trap rocks at former periods. Intense internal heat acting upon water, and evolving steam and gas, may be imagined to have been a cause adequate even to the elevation of continents; and it is possible to conceive, how a superincumbent mass of marine sediment, repressing the rise of molten matter to the surface, might, like a high pressure steam apparatus, have produced a powerful accumulation of the subterranean gaseous forces which were labouring to expand. But to pass, for the present, from this theoretical point, let us consider a few more facts from which we may legitimately draw our conclusions.

In the introduction it was announced, that within this region there were gradual transitions between all the formations which succeed each other. The reader, who has carefully examined the evidences and compared the sections, will find that this assertion has been completely borne out. He may, indeed, think it surprising, that in a country so disturbed by igneous rocks, this unbroken succession of the sedimentary deposits should be visible; yet he must recollect, on the one hand, that there are wide tracts wholly exempted from disturbance, and, on the other, that without volcanic eruptions, many of the inferior strata would never have been brought to the surface for our ex-

amination. In those districts, where igneous masses have been suddenly intruded at one point, and have as suddenly ceased to be evolved at others, the strata in the disturbed, when compared with those in the undisturbed districts, are necessarily found in unconformable positions. From this cause, the Silurian strata of Shropshire fold round the inclined and disrupted edges of the Cambrian Rocks, showing that these had been set on edge anterior to the accumulation of the younger deposits; whilst in Caermarthenshire, and partially at the Berwyn mountains, the links not being broken off, there are actual passages from the one system into the other. In Shropshire, the inclined position of the oldest deposits terminates abruptly with the disappearance of the intrusive rocks, and the younger strata of the tract, undulating in less disturbed masses, are necessarily unconformable to the older. In Caermarthenshire, all the sedimentary masses have been more or less conjointly elevated, thus demonstrating, that whilst in certain districts accumulations have been forming for a length of time, in undisturbed sequence, in other tracts their continuity has been destroyed by dislocations or volcanic eruptions.

If, from the facts before us, we attempt to unravel such problems, how much more difficult is the task of retracing in imagination the outline of the surface of the earth during the production of these varied deposits! Whence, it may be asked, was the detritus derived, which, layer after layer, was piled up in such stupendous masses beneath the then existing seas? However incomprehensible it may appear to those who have not studied the subject, geologists entertain no doubt that all our present mountains composed of sedimentary matter, were accumulated *beneath the sea* during countless ages; and, if so, other continents must have existed to furnish materials, though no traces of such lands now remain.

Again, how wonderful is the uniformity in mineral character which pervades such masses over large spaces! The black shale and schist, the red, grey and purple sandstone of the Silurian and Cambrian Systems, were once, as already stated, nothing more than the finely comminuted mud and sand which were spread out successively over the beds of great estuaries;—but how vast must have been the streams through which they were diffused! The united powers of transport of the Ganges and the Amazon must, indeed, have been in action during immense periods, to deposit masses of sediment so extensive, as those which we know were formed at that epoch in Europe, Africa, and America.

If the scale of these operations be surprising, equally so are the changes in the succession of deposits. The sediments poured forth to form the Cambrian and Silurian Systems, indicate by their structure and colour, either that the lands whence they were derived successively changed their outline, some portions being elevated and others depressed, or that the affluent streams of the great transporting channels were from time to time directed into new directions. Ascending from these ancient strata, the whole geological series, consisting of alternations of mud, sand, and lime, attests

the result of like mutations. Some, however, of these great sedimentary masses, such as the Old and New Red Systems, respectively prove the long continuance of similar conditions, whilst others (as the Oolitic System) bespeak in the varied structure and colour of the deposits, more rapid and frequent changes.

Combining in our survey then, the whole range of deposits from the most recent to the most ancient group, how striking a succession do they present!—so various yet so uniform—so vast yet so connected.

In thus tracing back to the most remote periods in the physical history of our continents, *one system of operations*, as the means by which many complex formations have been successively produced, the mind becomes impressed with the singleness of nature's laws; and in this respect, at least, geology is hardly inferior in simplicity to astronomy.

But to revert for a moment to the phenomena of destruction. Is it possible to contemplate the scenes of dislocation, where mountains have been severed, and their parts, once continuous, hurled into distinct ridges, and separated from their parent masses by vast intervals, without feeling astonishment at the intensity of the forces which were employed? Who can view the promontories and valleys of elevation shattered by great transverse fissures, without wondering at the means employed in their production? In them, not only have we proofs, that the solid strata have been heaved up on lines both parallel and devious, but also that they have been snapped asunder by numberless rents and cracks, some of which have become deep chasms occupied by rivers. How have the coal-fields been rendered accessible to man's use? Have we not shown, that many have been forced to the surface by volcanic action, and that some have assumed a basin shape, in consequence of their margins having been thrown into that form by a number of violent upcasts of the subjacent solid masses, which, wrenched from their original position, now converge towards a common centre? Need we recapitulate those curious changes in the lithological character of the deposits effected by igneous action; or endeavour to rouse the mind to a sense of the greatness of those powers, whatever they may have been, which produced the symmetrical jointed structure of mountains, and carried countless lines of parallel cleavage throughout regions of slaty rocks, in spite, as it were, of the original forms of the strata?[1]

Further, may we not advert to the striking phenomena which portions of this region exhibit, of the complete reversal of a whole range of formations? Can anything be more startling than the fact, that for many miles the stratified masses have been so completely overturned, that the last accumulated have been placed *under* those of anterior formation? Is it not difficult to comprehend how the upheaving force could be so in-

[1] The observations of Professor Sedgwick on the slaty cleavage of mountains are here alluded to. I may here further observe that Mr. R. W. Fox, of Falmouth, has recently endeavoured to show how parallel lamination (similar to slaty cleavage) may be produced in masses of moistened clay by long-continued weak voltaic action, proving thereby that this remarkable structure cannot be referred to any mechanical cause. (See Report of the Committee, Royal Cornwall Polytechnic Society, 1837.)

tense, that such sedimentary masses should be first elevated into vertical positions, and then overturned, or bent back upon their axes?

The mere announcement of these grand changes gives us a full perception of the magnitude of the scale and power of the forces employed; and we see in them a cause fully adequate to account satisfactorily for many of the results described under the head of drifted materials.

In the ensuing chapter we shall take into consideration the equally wonderful zoological phenomenon of the coexistence of similar species of animals in the most distant quarters of the globe.

In concluding the first part of this volume, or that which embraces descriptive geology, we would observe, that abundant proofs have been adduced to show, that the forces employed in dislocating the crust of the globe were of extraordinary intensity. These well-registered phenomena are, we contend, absolutely inexplicable without the intervention of paroxysms infinitely greater than any of which modern times furnish examples;—and yet we shall find, that such data, though drawn from the opposite extremes of the subject, are not in collision, and will not impede the onward march of our science.

Judging from the facts before them, geologists are entitled to look to a deep-seated and widely extended explanatory cause; and hence many have been led to believe, that all the ancient phenomena proving outburst and dislocation, have proceeded from a central heat, of which the volcanic ebullitions of past periods and the present are merely the external signs. Now, if the astronomer has correctly supposed that this planet was originally a semifluid mass, which by revolving on its axis assumed a spheroidal form; the geologist, examining into the nature of the oldest crystalline rocks, sees in them the clearest evidence of the effects of intense heat, which bursting out at intervals through sedimentary deposits, evolved the sheets of matter which constitute the axes and centres of many mountain chains. He infers that central heat has subsequently been the source and great agent of the mutations he traces[1], not only from the surpassing grandeur of the phenomena, but also because they harmonize with the probable relative conditions of such periods; for each succeeding accumulation of fresh sedimentary matter would, as before hinted, necessarily tend to repress the power of heat proceeding from within, whether in the form of actual molten matter or of gas and steam. Each great igneous eruption, carrying with it fresh materials for additional deposits to be spread out on the bed of the ocean, would in fact be auxiliary to the repression of similar eruptions in future, by adding new folds to the pre-existing crust which enveloped the central and heated nucleus.

The question therefore is, does Nature teach us, that the most violent dislocations are apparent in our geological phenomena? If (as I firmly believe) she does, and further impresses on us the belief of a former state of paroxysmal turbulence and chemical

[1] See the powerful essays of Cordier and Fourrier.

change, of much deeper rooted intensity and wider range than any to be found in our own period; then the theory of central heat, as propounded by the mathematician, finds its best supporter in the geologist.

Nor is this view incompatible with those principles which inculcate the doctrine of the *gradual* elevation and depression of *modern* continents. We have recently seen two of our first philosophers[1] maintaining, that a central heat being granted, the necessary result of the increment of fresh matter in one part, and its abstraction from another (as is now taking place), must produce such variations in the conducting media, that the result would be the gradual elevation of some parts of the earth's surface, and the depression of others. Hence, therefore, we infer that those principles which teach us to reason from the operations of the present day, are completely reconcileable with the doctrine of geological catastrophes; for a central heat being admitted, we see in it the source of great former revolutions, as well as of the gradual heavings and depressions of modern times.

He who had never extended his research beyond the phenomena of intense violence, so apparent in almost every mountain chain, would scarcely be brought to believe, that the agency by which these changes were accomplished, was the very same as that which produces modern vicissitudes. But he who examines the whole range of terrestrial phenomena will acknowledge, that they are all in harmony,—all proceeding from the same source!

Geology, therefore, in expounding the former condition of the globe, convinces us, that every variation of its surface has been but a step towards the accomplishment of one great end; whilst all such revolutions are commemorated by monuments, which revealing the cause and object of each change, compel us to conclude, that the earth can alone have been fashioned into a fit abode for Man by the ordinances of INFINITE WISDOM.

[1] Babbage and Herschel.

END OF PART I.

THE

# SILURIAN SYSTEM,

FOUNDED ON

## GEOLOGICAL RESEARCHES

IN THE COUNTIES OF

SALOP, HEREFORD, RADNOR, MONTGOMERY, CAERMARTHEN, BRECON, PEMBROKE, MONMOUTH, GLOUCESTER, WORCESTER, AND STAFFORD;

WITH

DESCRIPTIONS OF THE COAL-FIELDS AND OVERLYING FORMATIONS.

BY

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ETC. ETC. ETC.

IN TWO PARTS.

PART II.

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1839.

# PART II.

## ORGANIC REMAINS.

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## ORGANIC REMAINS.

## CHAPTER XLIII.

*Introductory View of the Distribution of Organic Remains in the Older Formations.*

GEOLOGY reveals to us the extraordinary fact, and without its aid the fact never could have been known, that as the globe passed from one condition to another, whole races of animals perished, and were succeeded by others with organizations adapted to the altered state of our planet.

On this phenomenon is based the fundamental principle of the identification of strata by their imbedded remains; the passage from one deposit to another being marked by a change in the animals which lived and died during the accumulation of each. Thus, although the fossils of any one great series of beds possess a common character, yet those which are found in the lowest and highest strata of a great formation are for the most part dissimilar in species, and often in genera.

This principle, so little adverted to in the early days of the science, and yet so vitally essential to its advance, has hitherto been chiefly tested by the examination of the tertiary and secondary deposits, and its complete development required, that succeeding observers should laboriously work out its application to the numerous older strata which are contained in the crust of the globe. In the progress of inquiry, this method of proof having been sometimes too minutely exercised, and at others too vaguely, has undeservedly incurred discredit. Some persons, for example, have endeavoured to show, that because within a limited area every succeeding stratum was charged with peculiar species, so we ought to find the same distinctions universally; while others, merely comparing lists of species in the works of authors of different countries, or erroneously identifying figures and descriptions of fossils, have inferred, that many species have a much wider range in the geological scale than experience confirms.

The only effective remedy for the scepticism engendered by such loose comparisons is to publish monographs, with figures of all the remains found in each group of deposits, the stratigraphical limits of which have been precisely defined by competent observers. This object having been in great measure accomplished in respect to the tertiary and secondary rocks, the inquiry has been recently carried down to the still lower strata of the Carboniferous System. We may, therefore, say that the chronological zoology of the science in England has been, on a general scale, systematically conducted to the verge of the ancient strata illustrated in this work; though from this step downwards in the series, it must be allowed, that the natural history of the fossils has never yet been directly connected with the order and arrangement of the rocks.

In the commencement of this volume, while sketching the previous state of our knowledge of these older formations, I pointed out the confusion which had been introduced by so applying the word "transition" as to embrace in one meaning, the Carboniferous, Old Red, Silurian and Cambrian Systems. If the Old Red Sandstone had been clearly separated from the Carboniferous System above and from the Silurian Rocks below it, the term "transition" (as formerly used by certain English geologists, and applied by them to the *lower* divisions only) might well have been retained. Seeing, however, that all the continental and most of our native writers had in the mean time extended the application of this word to the carboniferous deposits inclusively, there appeared to be no possibility of preventing confusion without the introduction of a distinct classification. In the previous pages it has I hope been clearly established, that the Old Red Sandstone and Silurian Rocks are completely distinct from the Carboniferous System, by order of superposition and lithological characters; and my present aim is to prove that they are equally distinct by their imbedded organic remains.

If this principle of classification, which is established in the arrangement of the tertiary and secondary deposits, be once admitted as respects the more ancient rocks of the British Isles, I have no doubt that in other parts of the world, where deposits of the same age occur, it will be found equally true. It is, in fact, only in countries like our own where all those strata exist, which rising from beneath a well-developed carboniferous system, connect it by unbroken links with the inferior slaty rocks, that such an inference can be sustained; and hence it follows, that no counter evidence can be received, when derived from tracts in which many of these links are wanting, or where the convulsions and alterations of the rocks have been so great, that the correct identification of their contents is impracticable. Still less can we admit the validity of arguments founded, either upon mere lists of fossils which may have often been erroneously identified, or simply upon the names attached to formations by geologists who have not studied the whole sequence of the deposits in question[1].

[1] On this point I may remark that a paper by Mr. Weaver on the south of Ireland, containing much valuable matter, has just appeared in the Transactions of the Geological Society, vol. iv. This memoir seems to warrant the necessity of the above caution. After separating the Carboniferous from what he continues to term

Looking, therefore, steadily to the object of this work, and restricting myself to that field of inquiry with which I am conversant, I distinctly maintain, what is asserted in the Introduction; that the fossils of the Silurian System here represented, and amounting in all to about 350 species, are, with the exception of a very few (chiefly doubtful casts), essentially distinct from any of the numerous and well-defined fossils of the Carboniferous System; and further, that the Old Red Sandstone which separates these two systems is also characterized by fossils peculiar to it. In testing this inference, I merely require, that if the organic remains of formations of dissimilar age are compared, they may be selected from well-known and clearly established *geological* types of such rocks. Having for a series of years collected fossils from every stratum of the Silurian Rocks, throughout a large region, in which the stratigraphical order is clear, I now present the results. Professor Phillips had previously completed a valuable monograph of the organic remains of the Carboniferous System. If the naturalist will compare the figures in these, the only two works yet published upon the older fossiliferous rocks, which combine geological description with zoological proofs, he will at once see the truth of my position.

Beginning with the *vertebrata*, are not the *fishes* of the Old Red Sandstone as distinct from those of the Carboniferous System on the one hand, as from those of the Silurian on the other? M. Agassiz has pronounced that they are so.

Are any of the *crustaceans*, so numerous and well-defined throughout the Silurian rocks, found also in the Carboniferous strata? I venture to reply, not one.

Are not the remarkable *cephalopodous mollusca*, the *Phragmoceras* and certain forms of *Lituites*, peculiar to the older system?

the "Transition Rocks," Mr. Weaver arrives at the conclusion, that a large number (between 60 and 70 species) of the fossils of these two systems are *identical*. I need not inform my readers, that my zoological data and inferences are completely at variance with those of Mr. Weaver.

Respecting the Irish case, it may be stated that Mr. James de C. Sowerby, whose authority is much cited in the memoir of Weaver, is of opinion that all the fossils therein enumerated, p. 21, as belonging to the *transition* limestone of Cork and neighbourhood, are, with one exception, characteristic fossils of the *carboniferous* limestone of England and Ireland; and therefore that they are of the *same* geological age as those which, in another part of the memoir, are described as *exclusively* belonging to the carboniferous strata.

Judging from the printed lists, Professor Phillips also thinks that the Cork limestone fossils are carboniferous.

Mr. Sowerby coincides with me in believing, that the only fossils alluded to by Mr. Weaver, *which really belong* to the more ancient rocks (Silurian, &c.) are those enumerated (pp. 10, 15 *et seq.*). Should this view be substantially correct, the south of Ireland, so far from offering evidence to contradict my classification, will eventually be found to support it.

From an inspection of Mr. Weaver's map alone, I cannot avoid surmising, that the localities where true Silurian fossils might occur, are those alone where such *have really been* detected, as the strata in those situations are separated from the carboniferous limestone by large masses of Old Red Sandstone. (See Smerwick Harbour, &c., on the coast of Kerry, and the east of Bon Mahon river, Waterford.) The Old Red Sandstone, that important feature of separation, being wanting in all the remainder of the country described, is it hazarding too much to suggest, that some of the limestones which there occur, and which are loaded with carboniferous fossils, may be outliers and remnants of the base of that system, which we know to be so vastly expanded and widely diffused throughout other parts of Ireland?

Is there one species of the *Crinoidea* figured in this work, known in the carboniferous strata?

Has the *Serpuloides longissimum*, or have those singular bodies the *Graptolites*, or in short any zoophytes of the Silurian System been detected in the well-examined carboniferous rocks?

And in regard to the *corals*, which are so abundant that they absolutely form large reefs, is not Mr. Lonsdale, who has assiduously compared multitudes of specimens from both systems, of opinion, that there is not more than one species common to the two epochs?

If, therefore, it should prove after all, that a *few* species of *conchifers* (an order of beings capable, perhaps, more than any other of enduring vicissitude), continued in existence, from the formation of the Silurian Rocks to the accumulation of the carboniferous limestone, how can their presence break down the individuality and separation of systems, established upon such a vast preponderance of direct zoological evidence in the other natural classes? Even should a few other *mollusca* in the two systems be considered identical, there is no doubt, that by far the greater number of them which truly belong to rocks rising from beneath the Old Red Sandstone, are distinct from those which inhabit the strata above that system.

Such evidences are therefore, as before mentioned, nothing more than additional supports of the important truth which geology has already established; that each great period of change, during which the surface of the planet was essentially modified, was also marked by the successive production and obliteration of certain races.

Let it not, however, be imagined that I wish to inculcate the doctrine, of every ancient formation having been tenanted by creatures absolutely peculiar to it. The large natural groups of strata only, or, so to speak, systems, can be thus distinguished. We have, indeed, ascertained to a great extent the distribution of organic life in the epochs anterior to our own, and we now know, that with each great increment of newly deposited matter, new animals appeared, and that while some vanished with the lapse of time, others unsuited to sudden changes were destroyed.

Among the secondary causes by which such results have been aided, the volcano and earthquake have assuredly been most prominent. We believe, therefore, that inasmuch as the outbursts of volcanic matter, in the region under review, have been numerous and often repeated, they must have materially operated in the destruction of animal life; but as we have shown that all the lines of eruption were *limited*, so we infer that no general destruction can have taken place; and hence it is, that this territory, when examined carefully and in all its parts, presents us with so many examples of a perfect "sequence" in the succession of the strata and the progressive development of their zoological contents.

Thus certain species, whether endowed with powers to resist vicissitude or living in those parts where few active agents of destruction were at work, continued to live

through long epochs; while others of a higher structure, passed away in comparatively short periods.

There is yet, however, a phenomenon of the highest importance, connected with the distribution of organic remains in the older strata, which has not been adverted to; namely, that the same forms of crustaceans, mollusks and corals, are said to be found in rocks of the same age, not only in England, Norway, Russia, and various parts of Europe, but also in Southern Africa, and even at the Falkland Islands, the very antipodes of Britain. This fact accords, indeed, with what has been ascertained concerning the wide range of animal remains in deposits equivalent to our oolite and lias; for in the Himalaya Mountains, at Fernando Po, in the region north of the Cape of Good Hope, and in the Run of Cutch and other parts of Hindostan, fossils have been discovered, which, as far as the English naturalists who have seen them can determine, are undistinguishable from certain oolite and lias fossils of Europe[1].

Another remarkable fact illustrating this point of inquiry is, that although the older fossiliferous strata often contain *vast quantities* of organic remains, the *number of species is much smaller* than in more recent deposits. Judging from my own labours, I can affirm, that after seven years devoted to this inquiry, the number of species collected at the end of four years was little less than the aggregate now published. The above resemblance, therefore, (if not identity) of certain forms, out of this number, which are found in opposite hemispheres, is the more surprising.

[1] The largest collection of fossils from the Himalaya, with which I am acquainted, was brought home by Lady Sarah Amherst, and being examined by Mr. James Sowerby was found to contain several Ammonites undistinguishable from our English species of the lias.

The specimens from Fernando Po and the opposite coast of Africa were collected by Capt. Sir C. Bullen, R.N., and when placed on the table of the Geological Society every person present who was conversant with lias fossils, thought these samples had been merely sent up from Lyme Regis (*Ammonites communis, &c.*).

The fossils from the Orange River, six hundred miles north-east of Cape Town, including *Astarte orbicularis* and *Gervillia aviculoides* of the green sand, and *Trigonia clavellata* of the oolite, were collected by Dr. Smith, the enterprising explorer of Southern Africa.

The fossils collected by Captain Smee in the Run of Cutch, are very numerous, and several of them, such as *Gryphæa dilatata, Trigonia costata, &c.*, are identical with English oolitic species. (See Proceedings of the Geological Society, vol. ii. p. 77.)

The fossils from the Falkland Islands were discovered by Mr. C. Darwin, and they appear to me to belong to the Lower Silurian Rocks.

It is well known that certain species of Trilobites are common to the older rocks of North America and various parts of Europe; the same fact has been since established repecting South Africa, through the labours of Dr. Smith above alluded to. At Cedarberg, one hundred and fifty miles north of Cape Town, he found an assemblage of fossils evidently composing an Upper Silurian group, in which are some species which mark the passage from the Old Red Sandstone to the Ludlow Rocks and others which are abundant at Ludlow and Wenlock. These fossils were first forwarded to me by my distinguished friend Sir John Herschel, and among them we observe the *Homanolotus Herschelii* (Nob.), Pl. 7 *bis*. f. 2., with *Calymene Blumenbachii* and other trilobites, associated with casts of shells undistinguishable from the following species figured in this work. *Cucullæa ovata, Leptæna lata ?, Orbicula rugata, Nucula, Turbo, Turritella* and *Conularia quadrisulcata*.

But it has been said, that a species in these old rocks has been often decided by a mere cast, grounds upon which no conchologist can pretend to set up real distinctions. Now to this objection I would first reply, that sharply defined casts may sometimes suffice to prove the identity of forms to be compared, and secondly, that it is by no means on such evidences alone, that my conclusions have been drawn; for in numberless instances the fossils of the Silurian System preserve their shelly covering as perfectly as the testacea even of the youngest deposits.

On this point, however, of specific identity (particularly in the case of very distant deposits) let us not insist too strongly. It is enough to state, that on comparing the fossils from different localities of each Silurian formation we find the closest agreement; certain forms being found in one formation, certain other forms in another; and by this means we have been able to determine the age of the rocks, and to verify the justness of the division by order of superposition.

Extending this mode of investigation to fossils obtained from other parts of the world, and comparing casts with casts, an identity of form as well as of muscular and other impressions will be at once admitted. It is on these grounds we assert, that while the Silurian System was in the course of deposition, similar *mollusks*, *crustaceans* and *corals*, lived in very distant parts of the globe, and where climates of very different temperature now prevail.

In the meantime we may appeal to our records in the rocks, and if each succeeding system is found to contain different species of animals, there can be no difficulty in determining, whether their former geographical distribution was or was not similar to that which now prevails.

Examining the strata with this view, we find that in the ascending geological series the quantity of species increases considerably as we approach the younger deposits, and that in proportion to this increase, their geographical distribution harmonizes more and more with that of existing nature. For example, in the older Tertiary strata (Eocene), there are scarcely any examples of shells identical, being found in opposite hemispheres, and in the younger Tertiary (Pliocene) absolutely none; though in these deposits the number of species is at least tenfold greater than in the ancient rocks under consideration.

Now if this position be admitted, it is manifest that it cannot be explained by reference to the present distribution of animal life. For not only has each latitude, in our days, its different products, but even in distant parts of the same latitude (and in the same hemisphere), the amount of variation of species is often very great.

Again, reverting for an instant to our argument in the last chapter, we must recollect, that it does not merely depend upon the wide area over which the sediment containing these fossils was spread, but also upon the fact, that these ancient rocks are of vastly greater thickness than any of the succeeding deposits, and must therefore have occupied a much longer period during their formation.

Hence it is that the geologist, whose science consists in unfolding the records of lost

epochs, is not manacled by present conditions, and if the phenomena to which he appeals convince him, that the former changes of the planet were of surpassing grandeur, he may also conclude, that some general cause must explain the distribution of the same species over distant regions. If the existence of formations, so nearly universal as respects the surface of the globe, be admitted, it would seem to be a fair inference, that however we may explain it, there must have *then* prevailed a generally equable temperature.

But let us pass from these general views to the immediate objects of this work.

The following pages and accompanying plates are intended to develop the amount of zoological mutation throughout a large portion of these ancient fossiliferous strata ; and the inference we obtain is, that most of the groups which graduate into each other by lithological and geological characters, exhibit also a true zoological transition. Thus, in reviewing this ancient succession in ascending order, we perceive a certain number of species common to the Upper Formations of the Cambrian System and the Lower Silurian Rocks ; and that while some of the Lower Silurian animals lived on to those days when the Upper Silurian beds were deposited, scarcely a single species which existed when the Silurian æra commenced, can be detected in the strata which mark its close.

Again, in proceeding upwards from the Silurian period into that of the Old Red Sandstone, we find in its lowest member, a partial intermixture of a few fossils, typical of the Upper Ludlow Rock or the last-formed beds of the Silurian System, associated with some new species ; and ascending higher amid these red deposits, we meet with fishes of entirely distinct genera and species, as unlike those of the Silurian æra as they are to those of the overlying Carboniferous System. In the upper division, however, of the Old Red System (though of enormous thickness) scarcely the trace of fossil animals has yet been detected, and hence we are unprovided with zoological links to connect the whole series, though I have no doubt that such proofs will be hereafter discovered, and that we shall then see in them, as perfect evidences of a transition between the Old Red and Carboniferous rocks, as we now trace from the Cambrian, through the Silurian, into the Old Red System.

When, therefore, it is asserted, that the fossils of the Carboniferous æra are dissimilar from those of the Silurian, the reader must bear in mind, that the strata so broadly distinguished, are separated by accumulations of enormous thickness, and that the vast time occupied in their deposit, accounts satisfactorily for an almost entire change in the forms of animal life.

The same order and change of species is apparent throughout the overlying formations. Thus, although there is a slight community of character between the upper members of the Carboniferous rocks and the lower strata of the New Red System, particularly in the plants[1] ; and although certain *mollusca* of the Magnesian Limestone

[1] I have adverted slightly in this volume, to the vegetables which may be found in the Silurian System ; for although I am persuaded of the truth of the induction of M. Adolphe Brongniart and other fossil botanists, that each geological period, from the tertiary down to the carboniferous deposits, is marked by a distinct Flora,

differ little from those of the coal measures, we cannot examine even that formation, still less pass onwards through the overlying red sandstone and marl without perceiving, that in the Sauroids of those days, we are surrounded by entirely new types of animal life, which conduct us by almost imperceptible gradations into the period of the *Ammonites* and *Belemnites*; and as we enter among those groups, we take leave of many of the generic forms, such as *Goniatites, Orthoceratites* and *Producti,* which abound in the older periods. Lastly, in the tertiary system which links on the ancient deposits with our own, we entirely lose sight of many of the former types, and are introduced to a series of animal forms much resembling those which are now in existence.—Such is the vast succession with which geology has made us acquainted[1].

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I have now only to observe, that in the following plates and their descriptions the organic remains are for the most part figured in the order in which they lie in the strata, a method by which the chronology of the subject is strictly maintained. Every fossil which occurs in more than one formation, is figured as belonging to that in which it is most abundant, and its repetition in other strata is explained in the text and lists. If naturalists should criticise this distribution, they will I hope excuse me when they consider, that my great object is to record perspicuously *a geological* succession.

Of the zoological department I have now to state, that the fishes are described by M. Agassiz; the mollusca and conchifers by Mr. J. de C. Sowerby; the corals by Mr. Lonsdale; the crustaceans by myself. I have further to mention with gratitude, that in various points of illustration I have been materially aided by Mr. Broderip, and that Professor Phillips, Mr. C. Stokes, Dr. Beck, Dr. Milne Edwards, and Mr. König have also contributed their assistance. The support, therefore, of such eminent naturalists must have greatly augmented the value of this division of the work.

the almost total absence of plants in the Silurian strata scarcely entitles me to enter upon this field of inquiry. It is, however, fair to state, that two or three plants, said to be species well known in the carboniferous strata, have recently been found in certain rocks of North Devon (considered to lie far below the culm or coal measures), and therefore as old, at least, as any portion of the Silurian System. If these data be eventually sustained, they will only compel us to suppose, that the changes in the physical state of the bottom of the sea, which produced the variations of its marine inhabitants, did not of necessity cause a change in the vegetable forms of the land; because the submarine operations may have exercised little or no influence upon aerial conditions or climate; and hence it may eventually be demonstrated, that the changes in animal and vegetable life do not continue to run parallel to each other beneath a certain limit in the order of the strata, or in other words during the earliest sedimentary accumulations. I confess that (judging from the analogy of the younger deposits) I at one time held a different opinion; but if the evidences above alluded to are substantiated, I have no difficulty in comprehending the rationale of the case.

[1] Although the stratigraphical order is strictly maintained in the collocation of the plates, the description sometimes embraces a class or family in the same chapter.—Thus the *Trilobites* of all the Silurian strata, described in Plates 7, 7 *bis*, 14, 23, 24 and 25, occupy one Chapter.

## CHAPTER XLIV.

### ORGANIC REMAINS OF THE OLD RED SYSTEM.

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*Introduction.—Fishes* (Pls. 1, 2 and 2 *bis.*)—*Mollusca, &c.* (Pl. 3.)

IT was a prevalent belief among geologists, when this work commenced, that few or no animal remains existed in the Old Red Sandstone of England. I first undeceived myself on this point by observing shells in the lower group or tilestones in Caermarthenshire, where they have been already alluded to (p. 183.). I afterwards discovered similar fossils in the great outlier of Clun Forest (p. 191.). These remains which occur in the very lowest beds only of the Great Red System are figured in Pl. 3.

Subsequently my attention was called to other singular forms, which Dr. Lloyd of Ludlow had discovered in the central parts of the system north of Ludlow, and in the hills between Tenbury and Leominster. From the shield or buckler-shape of the most remarkable of these bodies, some of the naturalists to whom they were first referred, considered them to belong to crustaceans, an opinion, however, in which their discoverer did not participate; Dr. Lloyd having originally suggested, that the bony structure apparent in some of the fragments appeared to exclude them from that class. The opinion, however, that these remains might be Trilobites did not long prevail; for when Mr. Lyell received specimens of unquestionable, though undescribed fossil fishes from the Old Red Sandstone of Scotland (1833), it was at once perceived by Mr. Lonsdale of the Geological Society, that our shield-shaped bodies from Herefordshire and Shropshire, were nothing more than the heads of the same singular genus of fishes, which at that time had not been seen by M. Agassiz. After being thus convinced, that these curious fragments really belonged to fishes, my geological examination during the following year brought forth similar remains from nearly every part of the great area occupied by the cornstone and marls of the Old Red Sandstone. Before the close of the summer of 1833 I had, indeed, traced them through large tracts of Hereford, Salop, Worcester, Monmouth and Brecon; and as they were always found in the same division of the Old Red System, they had become valuable auxiliaries in enabling me to identify subdivisions through England and Wales, and also to institute direct comparisons between the different strata of the Old Red Sandstone of England and Scotland. These remains occur both in the impure and sandy cornstones, and in the larger sub-crystalline

masses of limestone which have been described; but they are generally in fragments, there not having yet been any example of an entire fish found in England. This condition of the fishes is in some degree accounted for by their structure, as subsequently explained by M. Agassiz; though it might be supposed that their mutilated state would also seem to prove, that they had not been suddenly killed and entombed, but were long exposed to destructive sub-marine agencies, such as the attacks of animals, currents, concretionary action, &c., by which they were dismembered[1].

The fragments being usually of blueish and purple plum-colours, are strongly contrasted with the dull red tint of the surrounding rock, and thus the geologist has little difficulty in recognising even the smallest portion of these ichthyolites. Their peculiar colour is probably due to the presence of phosphate of iron, which has communicated a similar tint to the fishes of the Caithness schist. (See Trans. Geol. Soc., vol. iii. p. 142.)

Notwithstanding the most assiduous search by myself, assisted by Dr. Lloyd of Ludlow and the Rev. T. T. Lewis of Aymestry, no shells have yet been found associated with these fishes in the central or cornstone formation, wherein they most abound. In one situation, however, at the Daren near Crickhowel, I found the impression of a large scale of an undescribed species of *Holoptychus*?, in beds of younger age than the great mass of cornstones, and as I have also discovered the remains of other species in the lowest or tilestone division, the Old Red System may now be fairly said to be characterized throughout by ichthyolites peculiar to it.

That fishes existed in strata of the age of the Old Red Sandstone was first pointed out in the year 1827 by Professor Sedgwick and myself. In a geological memoir upon the Caithness schists, certain fossil fishes were described which we had obtained from strata, proved by actual sections to form part of the Old Red System of the Highlands, and it was therefore gratifying to find that one of the species which I detected in the very bottom of this system, near Ludlow, was recognised by M. Agassiz to be identical with the *Dipterus macrolepidotus* of the north of Scotland. That celebrated ichthyologist has, indeed, the real merit of having cleared away all the zoological obscurities which previously hung over this branch of our subject. Upon his arrival in this country (to which he was attracted by the well-merited honours conferred on him[2]) geologists at once placed all the fruits of their labours in his hands. The specimens of fishes col-

[1] The beautiful entire fish, *Cephalaspis Lyellii*, Pl. 1. f. 1., (of which species I have found hundreds of fragments in England and Wales) was discovered in the Old Red Sandstone of Forfarshire; and Professor Agassiz has with great propriety named it after the geologist who, in addition to his excellent works upon the general principles of our science, was among the first to explain the structure of his native county, Forfar. The ichthyolites of Forfarshire were, however, first described by the Rev. Dr. Fleming. See Edinb. New Phil. Journal, No. 45. p. 137.

[2] "The Wollaston Medal," presented to him by the Geological Society, 1834. The British Association for the Advancement of Science has since done honour to itself, by granting money to M. Agassiz to aid the publication of his great work.

lected for the illustration of this volume were submitted to his examination, and many of them have already been described in his admirable work (Récherches sur les Poissons fossiles). From that work, and from communications addressed directly to myself, the following descriptions are derived. In them we learn, that as some of these fossils are almost connecting links between crustaceans and fishes, the first rude guess of geologists was after all not remote from the truth.

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## FISHES OF THE OLD RED SANDSTONE.

CEPHALASPIS, Agass.

*Cephalaspis Lyellii*, Agass., Pl. 1. f. 1. and Pl. 2. f. 1, 2 and 3.
——— *rostratus*, Agass., Pl. 2. f. 4 and 5.
——— *Lewisii*, Agass., Pl. 2. f. 6.
——— *Lloydii*, Agass., Pl. 2. f. 7, 8 and 9.

CTENACANTHUS, Agass.

*Ctenacanthus ornatus*, Agass., Pl. 2. f. 14.

ONCHUS, Agass.

*Onchus arcuatus*, Agass., Pl. 2. f. 10 and 11.
——— *semistriatus*, Agass., Pl. 2. f. 12 and 13.

CHEIROLEPIS, Agass.

*Cheirolepis Traillii*, Agass. vol. ii. t. 1 *d* and 1 *e*. f. 4.
——— *uragus?* Agass. vol. ii. t. 1 *e*. f. 1, 2 and 3.

DIPLOPTERUS, Agass.

Pro. Brit. Ass. vol. iv. p. 75; Agass. vol. ii. p. 113.

CHEIRACANTHUS, Agass.

*Cheiracanthus Murchisoni?* Agass. vol. ii. t. 1 *c*. f. 3 and 4.
——— *minor*, Agass. vol. ii. t. 1 *c*. f. 5.

HOLOPTYCHUS, Agass.

*Holoptychus Nobilissimus*, Agass., Pl. 2 *bis*.

PTYCHACANTHUS, Agass.

*Ptychacanthus?* (spine of), Pl. 1. f. 9 and 10.

DIPTERUS, Cuvier.

*Dipterus macrolepidotus*, Agass., also Sedgw. and Murch., Geol. Trans., vol. iii. p. 143.

OSTEOLEPIS, Val. and Pent.

*Osteolepis macrolepidotus*, Val. and Pent.; Agass. vol. ii. t. 2. f. 1, 2, 3 and 4, and t. 2 *c*. f. 5 and 6.
——— *microlepidotus*, Val. and Pent.; Agass. vol. ii. t. 2 *c*. f. 1, 2, 3 and 4.

1. *Cephalaspis Lyellii*, Agass., Pl. 1. f. 1. and Pl. 2. f. 1, 2 and 3. (Récherches, vol. ii. tab. 1 *a*. figs. 1, 2, 3, 4 and 5; and tab. 1 *b*. figs. 1, 2, 3, 4 and 5.)

This species, so abundant in the Old Red Sandstone both of England and Scotland, is constituted by M. Agassiz the type of this genus, because the most perfect specimens yet discovered belong to it. The individual represented, Pl. 1. f. 2. (from the cabinet of Mr. Lyell) presents its dorsal aspect, the head being seen along its superior surface with its lateral prolongations. "This specimen," says M. Agassiz, "is particularly instructive, as it exhibits the junction of the head with the body, the disposition of the scales on the nape (nuque) and the middle of the back, and the points of insertion of the two dorsal fins. (Fig. 1. of the same Plate is also from a specimen in Mr. Lyell's collection.)

"The head of this fish is very large in proportion to the body, and occupies nearly one third of its whole length. The outline is rounded, in the form of a crescent, the lateral horns inclining slightly towards each other, while the anterior and central parts project much. These lateral prolonga-

tions are in fact less distant from each other, than they are from the round part of the snout. The middle of the head, including the region of the eyes, the cranium and the occipital crest, is elevated, whilst the sides and anterior edge are considerably dilated and horizontally extended, so that the two horned prolongations of the head overlap the sides of the body and extend considerably behind it, as seen in Pl. 1. f. 1. It is probable the head only appears to extend so much below the body, because the left wing of the disk has been bent back into a more vertical position than was natural to it. The eyes are placed in the middle of the shield, and near each other, but a little nearer to the end of the snout than the occipital crest. They appear to have been directed straight upwards, as in the *Uranoscopes*; at least such is their position in the specimens best preserved, and which are completely extended in their natural state, Pl. 2. f. 1. In Pl. 2. f. 2. where the sides appear to be somewhat contracted, the eyes are a little inclined towards the sides. Between them and in front of the orbits there is a triangular depression, which appears to have been occupied by the nostrils. Behind the orbit is another longitudinal narrow depression, bordered by two projecting crests, probably the parieto-frontal crests, so that the depressions would be found at the junctions of the frontal bones. These crests approach each other behind, and rise to form the occipital crest, which is very prominent, as is seen in Pl. 2. f. 2, whilst in f. 1. they are almost broken away. The posterior and middle portion of the head is nearly square, and is edged by the first series of scales, whilst the sides are very much sloped, and form the interior border of the lateral prolongations of the disk of the head, Pl. 2. f. 2. and Pl. 1. f. 2.

"The outline of the disk is surrounded by a bony plate, which, being bent back on itself, forms the inferior, as well as lateral margin of the head. Unable to determine the form and connection of the bones of the cranium, in consequence of the state of preservation of the head, (probably the result of its structure,) I proceed to notice the appearance of other parts of the surface of the head. The exterior surface is in a great measure covered by irregular scales, in form approaching to circular, the edges of which, notwithstanding they are more or less straight, are united in juxta-position, so as to form a pavement of scales, exactly similar to those which cover the heads of the *Ostracions*. Each of these scales has a convex centre, and hollow furrows diverging towards the edge, where they form a denticulation by which one scale is dove-tailed into another. The form of these scales varies extremely; the greater part are circular, but some are angular; the latter are attached to the straight edge of a scale, which on other sides is circular, and here and there small ones are seen filling up the intervals between the larger. These scales are bony, and their exterior surface enamelled. At the outline of the disk they are more confused, and the furrows of the enamel are parallel to the edge. (See a profusion of these scales in Pl. 2. f. 1. and magnified representations of them in Pl. 1. f. 7.)

"The bones of the head have also a fibrous structure, as may be seen in all the specimens where any fragments of it remain. This fibrous structure is most clearly observable on the internal surface of the disk as represented in Pl. 1. f. 1.; also Pl. 2. f. 1. in the place where the scales are removed; and even on the specimens which are merely casts, where it may be traced in relief upon the rock, on which the sinuosities of the interior surface of the bones of the head are left as impressions. On the anterior part of the disk the osseous fibres are directed straight forward; on the sides they are oblique, afterwards transverse; and lastly, in the lateral prolongations of the crescents of the head, they follow the direction of these prominent parts, and appear in general to diverge to every point from the sides of the cranium. The bones of the cranium itself, present a similar radiation between the parieto-frontal crests, as seen in Pl. 2. f. 1. The lateral prolongations of the head are thicker than its bony membranes, and narrow insensibly, so as to form a round and

compact point, which extends further back from the occipital crest (Pl. 2. f. 3.), and which is more detached from the body in consequence of the slope of the posterior border of the disk becoming wider as it recedes from the sides of the fish. The difference of form observable in Pl. 2. f. 1 and 2. and Pl. 1. f. 1 and 2. appears to arise solely from the different states of preservation of the specimens, and chiefly that in Pl. 1. f. 1. and Pl. 1 and 2. f. 1. the bones were as completely extended as their articulation would admit of, at the time when they were surrounded by the substance which formed the rock in which they are imbedded; whilst in the other specimens they were more pressed together, the pressure giving to them a narrower form.

"It is very probable that the heads of these fishes being so frequently found detached from the bodies, may be accounted for by the great difference which exists in the structure of these two parts, and above all in the disproportion of their dimensions and forms, which would offer a distinct resistance to the pressure, to which these animals must have been exposed. If, on the other hand, the heads usually present their superior surface to us, it is because their inferior surface, the cavity of the mouth, the branchial arch and sinuosities of the inferior bones of the cranium, are points of support comparatively more solid, and more adapted for sustaining the matter which has filtered into them, than a large surface slightly convex, which would naturally be detached from the rock wherever a separation was formed in it.

"The body most resembles that of certain fishes of the family of *Lepidoïdes*, but differs considerably from them in the two dorsal fins, in the anal being thrown further back, and in the singular scales with which it is covered. Its form is that of an elongated spindle, swelling out on the anterior parts, and narrowing insensibly to the end of the tail, which is proportionately very slender, since its diameter does not exceed a quarter of the width of the body near the nape of the neck.

"The first dorsal is placed on the most elevated part of the back immediately behind the occipital crest. Its existence is only known by the impression of its rays. On its anterior edge are two grooves, somewhat larger than those which succeed; there are certainly the impressions of two large rays, the first of which may have been short, and attached the whole length of the second, which extended probably to the extremity of the fin. It is impossible to decide whether there were any small imbricated rays. The other rays have left no other traces of their presence, than a striated appearance on the edge of this part of the back, to the middle of which they extended.

"The second dorsal is more distinct; its anterior edge is supported by a very large ray, the transverse articulations of which are very near each other, and on the edge of it are observable very small imbricated rays, closely pressed against the larger. The rest of the fin, which appears to have extended to the very slender pedicle of the tail, is only shown by a striated mark, parallel to the anterior ray, of which the striæ were the small blunt rays of the strong part of the fin. The relative position of the two dorsals is exactly indicated in the engraving, Pl. 1. f. 2. We here see, that behind the neck and on the posterior part of the back, the scales are not united, but have an interval between, on which the rays of the fin were inserted.

"The anal fin has not even left so distinct a mark of its presence; by comparing the two sides of the specimen represented Pl. 1. f. 1. we merely discover that it was placed further back than the second dorsal, so much so that its anterior edge corresponded to the middle of this dorsal. Its position is also indicated by the interruption to be remarked on the scales of the edge of the belly. The caudal fin had no large rays; the lobes are only indicated by the particular colour of the rock; the inferior one extends to the middle of the superior. Their insertion is very oblique, so that the prolongation of the pedicle (*pédicule*) of the tail is proportionately very long. Its superior

edge supports a large ridge of imbricated rays, very thick in proportion to the size of this fish, which enlarge from the posterior edge of the second dorsal to the middle of the pedicle, and which diminish again insensibly to its extremity. These little rays are very thick in proportion to their length. They are less strongly attached to the edge of the pedicle, and less inclined towards its extremity than most of the other genera of this family.

"The scales of the body are of a very peculiar form, and quite unlike those of any other genera. Fishes of the genus *Callichthys* only have also on their sides a series of very elevated scaly plates; but in the genus *Cephalaspis,* there is on each side only one range of plates, high and narrow, inserted transversely on the middle of the sides; whilst on the edge of the back and the belly there are series of little scales disposed obliquely to the extremities of those on the sides. On the pedicle of the tail, and on its prolongation, the scales have all the same form, they are rhomboidal, and diminish in size. Those on the centre of the sides Pl. 1. f. 4, are so high that their breadth exceeds their length eight or ten times, and they occupy more than half the height of the fish, at least in its anterior division. Towards the middle of the body they are less high, and below the second dorsal they end by being confounded with the little scales of the back and belly; so that the sides of the tail and its prolongation do not present the striking disproportion which there is in front, between the scales of the sides and those of the back and belly. The posterior edge of these high plates is straight, perpendicular to the longitudinal diameter of the fish, whilst the superior edge is cut off in a slope; the posterior angle is much more elevated than the anterior one. At the inferior edge, which is parallel to the superior, the obliquity of the angle is inverted. The exterior surface of these scales is ornamented with undulated furrows disposed in the direction of their greatest diameter. There are from 26 to 30 of these plates on the sides. The series of scales on the edge of the back are placed obliquely at the extremity of the high scales of the side, and run from top to bottom, from the front to the back, so that the opening of the obtuse angle which they form together is turned towards the head, and its summit towards the tail. In Pl. 1. f. 2. the disposition of this series is seen from the top, and their junction with the side plates; each one is composed of several scales as long on the anterior part of the back, as the ridges of the sides are wide, but which become smaller in proportion as the latter diminish in height, and are soon confounded with the scales on the edge. In each of these series there appears to be from four to five scales (f. 5.): on the edge of the belly the scales are turned obliquely backwards, to the extremity of the great transversal plates. This series in (f. 3.) are much narrower than that of the back, and appear to be formed of two scales only. Near the middle of the second dorsal all the scales are about the same size; those of the sides only are a little higher than they are long; but towards the extremity of the tail, they become more and more equilateral, and finish on the prolongation of the pedicle in a lozenge-shape, (f. 6.) of which the sharp angles are in the longitudinal direction of the fish. All these small scales appear smooth.

"The analogy in the structure of the scales of the genera *Callichthys* and *Cephalaspis,* appears to me to confirm the position I have assigned to the *Gonoidonts* and *Siluroïds,* in the order *Ganoïds* following the *Accipensers* or Sturgeons."

2. *Cephalaspis rostratus,* Agass. (Pl. 2. f. 4 and 5.) Récherches, vol. ii. t. 1 *b.* f. 6 and 7.

"This species evidently belongs to the genus *Cephalaspis* as characterized in the preceding description, and differs essentially only in the form of the head, which is narrow and much elongated. I have as yet only seen one good specimen, which is represented with its superior surface, fig. 6,

Agass., and f. 4 of this plate in profile. It is a head in the same state of preservation as fig. 3 of *C. Lyellii*; the impression only gives us the form of the head, none of the bones having been preserved. We can however trace some details marking the generic character, and which are not discoverable in the preceding species. I have named this fish *C. rostratus*, because the anterior portion of the head is prolonged to a pointed snout. The eyes are placed much further backwards on the disk of the head, nearly on the third posterior division, turned directly upwards, and still nearer each other than they are in *Cephalaspis Lyellii*; they appear to have had an oblong form (judging from the slight impression left of the orbits). Behind these we find also the parieto-frontal crests, which are very near each other and less projecting than those of *C. Lyellii*, and between which the occipital crests begin to rise. This head is much longer than wide, and its sides lessening rapidly, are more arched than the line which runs from the extremity of the snout to the neck, and which rises into a central crest from the anterior third of the head to the orbit. At the anterior extremity of this crest there is a triangular, longitudinal depression which may have been occupied by the nostrils, which must have been very near the end of the snout, and very distant from the eyes; on each side of this depression are two elevated points (fig. 6, *c c*), which lead me to suppose the superior maxillary bones were detached from the head, as in the genus *Hypophthalmus* and some other of the family *Silures*. These bones were perhaps prolonged in the form of barbs on the sides of the head, and were inserted in the cavity formed by these elevated points. The piece denoted by *o* appears to be the ethmoid bone, rounded at its anterior edge, and in front of which the intermaxillary bone formed the end of the snout and the reflected edge of the sides of the head. In this part of the impression are seen some traces of this bone, the surface of which is striated longitudinally, while its fracture presents a granulated structure. I dwell particularly on this peculiarity, and especially on the striated surface being seen distinctly as well as the granulous structure of the bone, in a specimen which evidently belongs to the genus *Cephalaspis*. This circumstance, joined to that of the lateral bones of the head being bent back towards the inferior surface, will facilitate the determination of the other species. Towards the region of the eyes are also seen two lateral prolongations, which appear to be the equivalents of the horns of the crescent of *C. Lyellii*. On the right side of the head it is evident that the inferior surface is longitudinally striated; on the left side there is a portion of the bone, the surface of which is striated in the same manner; on both sides is seen the granular structure of the bone. On the posterior edge of the left side there is a portion of the lateral divisions of the head uninjured, on the exterior surface of which may be observed similar longitudinal striæ, as on the impression of the inferior surface at the edge of its fracture. Between these two surfaces we again discover the granulous structure of the bone, and distinctly see that the striated surfaces are of a different substance; that it is a coat of enamel covering the bones of the head[1]."

### 3. *Cephalaspis Lewisii*, Agass. (Pl. 2. fig. 6.) Récherches, vol. ii. t. 1 *b*. fig. 8.

Of this species M. Agassiz says, "The specimen here figured is the only individual yet known to me of this species. It is a simple impression in relief of the head, on the sides of which there are some traces of organic substance. This impression, moreover, is so little characteristic, that it would be impossible to decide on the genus to which it belongs, if it did not present in some

[1] This species has at present only been found at Whitbatch, in the central portion of the Old Red Sandstone: Dr. Lloyd pointed it out to me, and stated from whence the specimen described was taken.—R. I. M.

parts a striking analogy with *C. rostratus*: thus, at its anterior extremity we find again exactly the same piece which I have designated as the ethmoid bone, with this difference, that here the impression of this bone is cut off square on its anterior edge; its lateral edges being straight and parallel to each other, and its posterior edge advancing towards the disk of the cranium by a narrower pedicle. The posterior border of the head is truncated as in *C. Lyellii* (Pl. 2, fig. 3,); but it is directed more obliquely forward, and elevated on each side so as to form a sort of hinge, as we often observe on the articulated borders of the rings of certain crustaceans. These elevated edges do not however join at the nape of the neck, which is depressed. On exposing this fossil to the light so as to exhibit all its inequalities, a line is distinctly traceable on the centre of it, extending from the ethmoid bone to the most elevated part of the cranium, the surface of which is completely round. On the sides of the disk is seen a sinuous furrow, which is lost in front in the edge of the impression, and at about the place where, in the *C. rostratus*, we perceive the two lateral elevations. The lateral edges of the head, especially on the posterior part, are flattened in the same manner as in the *C. rostratus* with this difference only, that in *C. Lewisii* they are perpendicular towards the junction of the head and body, and inclined outwards in their anterior and middle parts. On the left side is still seen some trace of the inferior surface of the bones of the cranium, and immediately at its edge, and on the posterior and inferior angle of the head, there remains a fragment which displays the granular structure of its substance, and which presents a perfect identity of organization with *C. rostratus*. In the *C. Lewisii*, however, I have not been able to trace any lateral prolongation in the shape of a horn[1].

"The head has something very remarkable in its form: the posterior part is narrowed and more arched than the middle part, which is flattened and dilated laterally; the snout is also flat; the disk has an oval form, truncated at its two extremities."

This species was found in the Old Red Sandstone of Whitbach by Dr. Lloyd, together with *Cephalaspis Lloydii, &c.* It was named by M. Agassiz, at my request, after the Rev. T. T. Lewis.

4. *Cephalaspis Lloydii*, Agass. (Pl. 2. f. 7 and 9.) Récherch., vol. ii. t. 1*b*. f. 9, 10 and 11.

"This species resembles the preceding in the general form of the head (the only part preserved amongst the numerous specimens I have seen) except that its anterior edge is rounder, and its posterior extremity less narrow. *Of the four species this is the one, the head of which at first sight least resembles that of a fish. In the specimens where the superior surface is preserved, it is difficult to divest oneself of the idea, that these fossils are the shells of some molluscous animal; for so completely regular are the striæ, that they perfectly resemble the lines of growth of the testacea.* On a nearer examination, however, these striæ are disposed differently from those of the shells of any mollusks; for even if we were disposed to consider these disks the shells of patelliform mollusks, or even of any conchifer, the disposition of the striæ would at once contradict such hypotheses. In reality these striæ are disposed on the sides of a central line running from the front to the back of the disk, and offering in the posterior part a perfect parallelism, whilst on its anterior part they follow its curvature, and in no respect resemble the concentric lines, formed by the new plates of shells in their growth. By comparing many broken specimens of these fossils it is evident, that this striated surface *is a coat of enamel*, distinct from the substance which forms the solid part of the disk; and that these striæ are grooves in the superficial part of the specimen, and not the ele-

[1] Fig. 8. represents a horn of the disk of one of the heads of *Cephalaspis* before described.

vated edges of the successive plates of growth. A clear proof of this is, that on making a transversal cut through the shell, nothing is perceptible on one side but small perpendicular clefts which terminate abruptly, and on the other, notwithstanding the regularity of these striæ, they are sometimes distinctly bifurcate. Finally, their similarity on both sides of the disk, without the least trace of a longitudinal division on the inferior layers of the substance, is a character which does not in any way accord with what is known to us in the enlargement of mollusks, and in the scales of the tail of crustaceans; whilst the analogy of these disks, with the heads of the *Cephalaspis* which have been just described, is more striking the more they are examined in detail.

"The head of this species is a more obtuse oval than the preceding; its anterior edge is completely circular: we can, however, evidently see the impression of an ethmoid bone similar to that of *C. Lewisii*, but narrower and longer; it was even decidedly longer than it appears to be in fig. 9; the original of which is broken on its anterior edges. The posterior border of the disk of the head is cut off obliquely as in *C. Lewisii*, but it is not raised up. The lateral edges are inclined uniformly to one side, and follow the general curvature of the arch of the head, which is nowhere depressed on its anterior part, as in the preceding species. Besides the coat of enamel which forms the exterior surface of the disk, and which is particularly well seen on the right and interior side of fig. 9, as well as on a fragment preserved towards the posterior edge of this same specimen, there may also be distinguished two other layers of very different structure: one, which is the centre of the shell, has a granulous structure similar to that of the bones of the chondropterygians, and perfectly identical with that of the plates in *C. rostratus*; the other, which is the inferior layer, decomposes in laminæ superposed one to another, like the plates of growth in molluscous shells. This last layer is thicker than the other three. In the specimen (fig. 7.), that in which the form is best preserved, no plates are seen except those of this third coat, which in part cover the raised impression of the inferior surface of the head. In fig. 9, on the contrary, at the edge of the disk, we recognize first the exterior coat, under which the middle coat is concealed, and a little further in the interior of the cast, the plates of the inferior coat. Finally, in fig. 8, is seen a fragment so broken as to present the *three* coats in their natural order of *superposition*.

"There is no trace visible on the sides of the head of any horn-shaped lateral prolongation any more than in the *C. Lewisii*. *These two species ought perhaps, therefore, to be generically separated from* C. Lyellii *and* C. rostratus.

"From what has already been said, the structure of the head of the *Cephalaspis resembles singularly that of the shell of crustaceans, which possess also an exterior coloured layer, under which is found a layer of a granulous structure, and then a layer of lamellar structure; and it was not without long deliberation that I decided on considering the fossils represented in figs.* 6, 7 *and* 9., *as the heads of Cephalaspis, rather than the terminal scales of some unknown crustacean.* It is very extraordinary that shields of which the ichthyological characters cannot be mistaken, in the species represented in figs. 1, 3 and 5, one of which at least has been found with its body and fins, should have exactly the *same structure* with other disks that might be supposed to be the *tails of trilobites*. The difficulty of deciding on these fossils is greater, because the buckler and tail of many species of trilobites have also the outer layer of their shell ornamented with furrows similar to those on the head of the *Cephalaspis*, and their edges sometimes raised up as a border, like the posterior edge of *C. Lewisii.* The constant presence, however, of the piece which seems to me to be the ethmoid bone, and the longitudinal ridge along the middle of the disk, seems to decide the question, and compel us to place all these specimens in the class of fishes, and to look upon them as the heads of *Cephalaspis*, or of some nearly allied genera. Their particular structure requires the greatest circumspection in

establishing species, in order to avoid the chance of considering as peculiar species those specimens where the exterior layer having been destroyed, the surface of the disks exhibit a totally different aspect. Similar mistakes have already been made in the class of crustacea, among which the inferior surface of the shell has frequently a different aspect from that of the superior, so that their casts or impressions have no resemblance to each other." (See Chapter on Trilobites.)

The *Cephalaspis Lloydii* occurs in several situations in the cornstone of Herefordshire, Shropshire, Worcestershire, &c., and in the same localities with the *C. Lyellii*. It has with great propriety been dedicated to Dr. Lloyd of Ludlow, who first made known to me the existence of fishes in the Old Red Sandstone, see p. 180, and whose collection has supplied the greater number of the forms here described.

### *Ichthyodorulites.*

"The Ichthyodorulites of the Old Red Sandstone," observes M. Agassiz, "belong to distinct species of the genera *Onchus* and *Ctenacanthus*, some species of which exist in your Carboniferous, Old Red and Silurian Systems. These bony spines are more or less arched, and grooved by longitudinal furrows, separated by round ridges forming ribs. In the greater number of the species, these ridges cover the whole surface of the fins: there is, however, one species of *Onchus*, the posterior side of which is partly smooth. The great distinction between this genus of Ichthyodorulites, and the large species of *Hybodus* of the lias (and New Red Sandstone)[1], to which they have some resemblance in the arrangement of their longitudinal furrows, is, that their posterior edge has no sharp points (piquans) or teeth, while in the genus *Hybodus* there are on that side strong points which are arched downwards."

### *Onchus arcuatus*, Agass. (Pl. 2. figs. 10 and 11.; Récherch. vol. iii. t. 1. figs. 3, 4 and 5.)

"This genus is easily distinguished. It embraces certain *cartilaginous fishes*, the dorsal spines of which only have yet been discovered.

"Dorsal fins large at their base, very much bent backwards, narrowing rapidly towards the superior end, furrowed along the whole of their surface by grooves parallel to the posterior margins, between which pretty strong ribs rise up, which so terminate as to give the anterior edge a toothed aspect. It is the largest species of the Old Red System, though inferior in size to some species of the Carboniferous Limestone."

### *Onchus semistriatus*, Agass. (Pl. 2. figs. 12 and 13.; Récherch. vol. iii. t. 1. f. 9.)

"Characteristic though imperfect fragments," observes M. Agassiz. "The posterior portion of the lateral faces of these fins is smooth, but the anterior part is grooved with numerous longitudinal furrows, between which are delicate flattened ridges. As the other species of *Onchus* are channeled all over, this form may, after all, belong to a distinct genus, but the imperfect condition of the specimens I have seen does not permit me to establish it."

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[1] A dorsal spine of *Hybodus* has recently been found in the Keuper Sandstone of the red marl of England, which, appearing to differ from any published species of Agassiz, Mr. Strickland and myself have called "*Hybodus Keuperi.*"—See Proceedings of the Geological Society, vol. ii. p. 563.

### *Ctenacanthus ornatus*, Agass. (Pl. 2. f. 10.; Récherch. vol. iii. t. 2. f. 1.)

"This fragment," says M. Agassiz, "is probably derived from the middle of a dorsal fin. Imperfect as it is, the characters of the fins of the genus *Ctenacanthus* are easily distinguished in *the furrows and longitudinal parallel ridges, with transverse folds*. This species differs from its congeners in the Carboniferous Limestone (*Ctenacanthus major*, *C. tenuistriatus*, *C. brevis*) by the tenuity of the longitudinal ridges, which lie very near each other, and by the delicacy of the transverse folds. The interior cavity of the fin appears, proportionably, very large, and the surrounding walls more slender than in the other species."

Locality, near Sapey, Worcestershire: found with other ichthyodorulites by Mr. H. E. Strickland; also north of Abergavenny where I have myself observed it.

### *Ptychacanthus*? Agass. (Pl. 1. figs. 9 and 10.)

It is with great doubt that the fragment, f. 9., of which f. 10. is an enlarged representation, is referred to the genus *Ptychacanthus*, Agass. "If this form should eventually be ascertained to belong to *Ptychacanthus*, still," says M. Agassiz, "the species is quite distinct, and unlike those of the Carboniferous Limestone." The fragment is supposed to be the portion of a dorsal fin, because its transverse section exposes a central cavity.

The above ichthyodorulites, or portions of them, are sometimes abundant where few or no specimens of the head of *Cephalaspis* can be detected. I have observed them in various parts of Herefordshire, near Abergavenny, in Brecknockshire, and also in the north-western district of Worcestershire.

### *Structure of Ichthyodorulites.*

M. Agassiz conceives that these fossil-dorsal spines belonged to cartilaginous fishes, the other portions of the animal having been destroyed. Some doubt has recently been thrown upon this view by Mr. Connell of Edinburgh, who, having analyzed these fossils from the limestone of Burdie House near Edinburgh, has found in them the same constituents as in the bones of the osseous fishes, notably of the pike.—Trans. Roy. Soc. Edin., vol. xiii.

In writing to me concerning this analysis, M. Agassiz thus expressed himself: "So far from fearing that I have misunderstood the nature of Ichthyodorulites, in referring them to *cartilaginous* fishes, instead of viewing them as fins of *Balistes* and *Silures*, as was formerly the case, I believe that the result obtained by Mr. Connell is a confirmation of my opinion; at least the texture ('contexture') of the spines of *Spinax* and *Trygon* which I have examined with this object, coincides completely with that of the bones of the bony fishes, and differs in consequence from the other portions of the skeleton of those fishes which are cartilaginous. It would, therefore, be very important to be assured by chemical analysis, whether the spines of the existing cartilaginous fishes (*Spinax*, *Trygon*, &c.) have also the same composition as the fossil Ichthyodorulites."

To determine this point, so important in the classification of M. Agassiz, I procured from Mr. Yarrell a serrated spine of one of the rays of a cartilaginous fish, of which he says, "whether this belongs to a species of *Trygon*, or to a species of one of the allied genera *Myliobatus* or *Cephalopterus*, all three of which are furnished with similarly serrated spines, I am unable to determine."

I next obtained from Dr. Mantell a smooth spine of the *Spinax acanthias* (the common "Bone Dog" of our shores).

The analysis of these two bodies was most obligingly undertaken by Dr. Bostock, who has arrived at the following conclusions[1].

"The larger of the bodies, *Trygon*, was first examined; the weight of the whole was very nearly 60 grains. For the purpose of ascertaining the proportion of the animal matter to the earthy salts, portions of it were respectively exposed to a red heat in a platina crucible for about half an hour, and digested for 24 hours in diluted muriatic acid. By comparing the results of these processes it appeared that the proportion of the animal and earthy ingredients was as 35·1 to 64·9. The muriatic solution was then examined, and was found to consist of a combination of the phosphate and the carbonate of lime, in the proportion of 49·15 to 15·65, making the composition of the entire substance as follows:

| | |
|---|---|
| Animal matter | 35·1 |
| Phosphate of lime | 49·15 |
| Carbonate of lime | 15·65 |
| Loss | 0·1 |
| | 100·00 |

"The structure both of the animal and the earthy matter appeared to be entirely fibrous, without any cellular or laminar arrangement, as is generally the case in bone, at least in the bones of the mammalia. The whole of the body presented an homogeneous appearance, there being no central cavity nor any obvious difference in the structure or consistence of its different parts.

"The smaller body (*Spinax acanthias*) differed essentially in its structure from the above; it consisted of an external shell, containing a quantity of loose membranous matter very similar to the root of a quill. The external shell differed obviously from the larger body in not exhibiting any fibrous appearances, so that when it had been either calcined or acted upon by the acid it lost its form, in the first case being reduced to a number of irregular fragments, and in the latter to a mere pulp. The proportion of animal and earthy matter seemed to vary considerably in its different parts, the former predominating in the root and the latter in the tip. This body also differed essentially from the larger in the nature of its earthy salts, which were found to consist almost entirely of the phosphate of lime, the carbonate being in a very small and nearly inappreciable quantity. The total weight of the smaller body was 4·9 grains."

This analysis of Dr. Bostock has, therefore, effected the desired object. It enables us to infer, that the original views of M. Agassiz concerning the nature of ichthyodorulites are completely borne out; for the quantity of earthy and bony matter in these dorsal spines of existing cartilaginous fishes is so great, particularly in such fishes as the *Trygon, Myliobatus, Cephalopterus, &c.*, that we may well conceive how, if imbedded in sand or mud, such bodies might be preserved as permanent relics, while every trace of the other parts of the soft and easily destructible animals to which they belonged would be entirely obliterated.

[1] Dr. Bostock will, I hope, soon add to his well-earned reputation as a physiologist by completing an extensive analysis (in which he has already made much progress) of fossil organic remains of all ages, indicating the processes by which they have been converted into their present condition.

*Dipterus macrolepidotus*, Sedgwick and Murchison. (Geol. Trans. vol. iii. p. 143. Pl. 15, 16 and 17; Agass. vol. ii. p. 117.)

The genus *Dipterus* was established by Cuvier from specimens which I sent to him from Caithness in the year 1827. In the following year, Professor Sedgwick and myself having visited the North of Scotland, we described the general structure of that country, including the black schists and flagstones of Caithness, in which the *Dipteri* are contained, and we then expressed our belief, that these strata were, in part, the equivalents of the Old Red Sandstone of England. That opinion is now confirmed by independent zoological evidence, for I have since detected the above-named species (which is very prevalent in the North of Scotland) in the lower beds of the Old Red Sandstone, at the Tin Mill near Downton Castle, Herefordshire.

This genus was at first separated by Valenciennes and Pentland into 4 species (see Geol. Trans. vol. iii. p. 143.), but after an attentive examination of a great variety of specimens, M. Agassiz, who attempted to class these fishes in the genus *Catopterus*, has definitively concluded, that although the genus *Dipterus* ought to be retained, the supposed four species are only differently modified forms of the same animal.

The generic character of the *Dipterus*, as now confirmed by M. Agassiz, consists in "*Two dorsal fins opposite to two similar anal fins, with a caudal fin conforming to that of the genus Palæoniscus, in having the vertebral column prolonged into the extremity of the tail.*"

Having as yet discovered small fragments only of the *Dipterus* in the Old Red Sandstone of the Silurian region, I refer above to the figures of this genus in the Transactions of the Geological Society, and to M. Agassiz's work, vol. ii. tab. 2*a*. p. 115.

*Holoptychus Nobilissimus*, Agass. (Pl. 2 *bis*. f. 1, 2, 3, 4, 8 and 9?)

This splendid specimen, of which f. 1. is a reduced sketch and which measures 2 *feet* 4 *inches by* 12 *inches*, was discovered in the Old Red Sandstone at Clashbinnie, near Perth, North Britain, by the Rev. James Noble, and was sent to me by him for the illustration of this work[1]. A drawing of it having been forwarded to M. Agassiz, he has favoured me with the following description:

"I am delighted with the fish represented in your drawing. It is a magnificent specimen, the discovery of which is of great value in advancing my researches. I was previously acquainted with fragments of several different species of the same genus, found at Gamrie and Burdie House in Scotland, and also in the coal-field of Staffordshire from which you sent me specimens. This individual, however, will at length enable me to define precisely the characters of the genus which I named *Holoptychus* from the folds of the scales. I had, it is true, seen detached scales of this species in

[1] It is to my friend Sir John Robison, Sec. Roy. Soc., Edinb., that I owe the appearance of *Holoptychus Nobilissimus* in this work. He presented a rough drawing of this ichthyolite to the British Association for the Advancement of Science at the meeting at Bristol, on which occasion I was much struck by its form, and was persuaded, that if properly described and examined by M. Agassiz, this splendid specimen would throw a new light on the fossil fishes of the Old Red Sandstone. Sir J. Robison having explained these circumstances to the Rev. J. Noble, that gentleman sent the original to my care, and thus M. Agassiz has been enabled to make an important improvement in his description of certain forms belonging to this fine type, which previously remained in obscurity or were assigned to other genera.

the possession of Professor Jameson and Dr. Buckland, but so imperfect, that before I was acquainted with those of Gamrie, which convinced me of my error, I intended to refer them to my genus *Gyrolepis*. Compare my chapter on *Gyrolepis*, (p. 172. 5 liv.), and particularly the article *Gyrolepis giganteus*, which is the fish you have sent me, and the name of which must now be changed." (The figures of it have, fortunately, not yet appeared.) M. Agassiz then proceeds to show that the fish in question has no relation to the accipenser or sturgeon with which it had been compared. "No sturgeon has similar scales. In the genus *Accipenser* there are only 5 rows of 'ecussons' scutcheons upon the back and sides, whilst this specimen proves that the whole surface of the *Holoptychus* was covered by them, as, indeed, I had perceived in various specimens found at Burdie House and Gamrie. Not one, however, of these species had conveyed to me so complete an idea of the characters of the genus as your specimen; and since, for the reasons assigned, its generic name must be changed, I see no inconvenience in also changing the name of the species, and in adopting, instead of *giganteus*, that which you suggest in honour of the discoverer, Mr. Noble, (*Holoptychus Nobilissimus*); the more so, since the species found in the carboniferous deposits at Burdie House is of as gigantic dimensions as that of the Old Red Sandstone."

"The generic characters consist in the peculiar structure of the scales, the enamelled surface of which is marked by large undulating furrows. Another characteristic feature is in the distant position of the ventral fins, far removed towards the tail, and much nearer the anus and anal fin *than in any other genus* of the family of *Ganoids*. Lastly, the arrangement of the branchial 'branchiostègues' rays is very remarkable, for they form two large plates between the branches of the inferior jaw, as in the genus *Megalichthys*. They are perfectly well seen in this specimen, and are of a *triangular shape*. What is perhaps most striking in this Old Red species, is the small size of the head in comparison with the body; for the outline of the two branches of the inferior jaw, which are narrow, are so clearly seen as to enable us to judge of the size or rather length of the head, which was certainly short and obtuse. The structure of the 'nageoirs,' the rounded form of the ventral fin, and the manner in which the rays of its anterior edge are insensibly prolonged, coupled with their relative thinness, are also very marked distinctions, and the same may be said of the anal fin and the disposition of its anterior edge. It is to be hoped we shall at some future day discover a specimen, placed in profile, which will enable us to decide the position of the dorsal fin and the fin of the tail. (The tail is wanting in this specimen.) This individual is lying on its back, and the attitude is very expressive; for it proves that the fish was naturally of a depressed form, 'plutôt déprimé que comprimé,' and not compressed by force. In fact, whenever flat fish are found placed on their backs or bellies in the rock their scales are always deranged, and it is only when they are naturally very *round*, or even depressed (déprimé), that the ventral scales preserve their natural position as in this example."

In Plate 2 *bis.*, a ventral scale of *H. Nobilissimus*, natural size, is given, f. 2. Fig. 3. is probably a scale or portion of the operculum, also of natural size; and being found in the same quarries of Clashbinnie, is also supposed to belong to *H. Nobilissimus*; as well as the very remarkable form, f. 4, which exhibits the toothed processes beneath the scales.

Does the tooth (Pl. 2 *bis.* figs. 8 and 9.) belong to this genus or to *Megalichthys*? It was found with other remains of fishes (such as large scales of *Holoptychus*, figs. 2 and 3), four miles to the south of Elgin, by Mr. Martin of that town, who, together with the Rev. G. Gordon, has made considerable collections of the ichthyolites of that neighbourhood. These remains occur in pretty highly inclined strata of coarse, slightly calcareous conglomerate, very low in the system of Old Red Sandstone, for the beds dip under the cornstones of Murrayshire, described by Professor Sedgwick and myself.

Mr. G. Gordon believes, that from their position, the beds with ichthyolites are probably of the same age as those of Clashbinnie in Perthshire, and of Strath Eden and Drum Dryan in Fifeshire.

I owe this information to Mr. J. Malcolmson, F.G.S., who having recently brought away specimens from the district, has obligingly enabled me to figure the conical tooth, and other portions of fishes found in the same quarries, figs. 5, 6, 7.

I may here remark, that although I have never yet found a perfect specimen of *Holoptychus* in the Old Red Sandstone of England, I have now no doubt, that the large scale which I detected in the Old Red Conglomerate near Crickhowell (p. 175) is identical with the scales which occur in Perthshire, Murrayshire and Caithness. (Pl. 2 *bis.* f. 3.)

M. Agassiz must determine the genera and species to which the other remains of fishes found near Elgin may belong. (Figs. 5, 6 and 7, are drawn from specimens belonging to Mr. Malcolmson.)

The great thickness of the bony matter which supports the scaly covering (figs. 5 and 6.) is very remarkable. It was this structure, so apparent in some of the Caithness fossils, which led Professor Sedgwick and myself to refer them to the class of reptiles. Geol. Trans. vol. iii. p. 144.

## *Diplopterus*, Agass.

The remarkable ichthyolite, which enabled M. Agassiz to establish the genus *Diplopterus*, was found by Dr. Traill in Pomona, Orkney, the sandstones and schists of which were previously shown to belong to the Old Red System.—Sedgwick and Murchison, Geol. Trans. vol. iii. p. 141.

M. Agassiz has not yet fully described this genus, though he tells us that it is of "the family of *Sauroid fishes*. Like the genus *Dipterus*, it has two dorsal opposite two anal fins, but the caudal fin is of a very peculiar form; the throat is very large, and the jaws are armed with *large conical teeth*." Récherches, vol. ii. p. 113.

## *Osteolepis.*

This generic name was given to fossil fishes of Caithness (collected by Professor Sedgwick and myself) by M. Valenciennes and Mr. Pentland; Geol. Trans. vol. iii. p. 143. The genus has since been found in the Orkney Isles by Dr. Traill, and M. Agassiz has continued to use the name first assigned to it. Two species occur in Caithness and the Orkney Islands (*Osteolepis macrolepidotus* and *O. microlepidotus*), while a third, *O. arenaceus*, Agass., is found at Gamrie. As this genus has not yet been found in the Old Red Sandstone of England, I refer my readers to the work of M. Agassiz for the description of the Scottish species.

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The reader may perceive that there are yet two genera of Ichthyolites enumerated in the preceding table, the *Cheiracanthus* and *Cheirolepis*, Agass., to which I have not adverted. Through the researches of Dr. Traill, who found the *Cheirolepis Traillii* and *Cheiracanthus minor*, Agass., in Pomona, Orkney, there is no doubt that these genera belong to the Old Red System.

Other species of these genera have been found at Gamrie, Banffshire, in which locality they were first mentioned by myself, though I never examined the relations of the strata. Those relations have since been described by Mr. Prestwich, in an able memoir on the coast of Banffshire, and according to him, the nodules containing the Ichthyolites are imbedded in an argillaceous, horizontally

stratified deposit, which is unconformable to the adjoining masses of Old Red Sandstone. On the other hand, I have recently been informed by Mr. Malcolmson, that Mr. Miller of Cromarty (who has made some highly interesting discoveries near that place), pointed out to him *nodules resembling those of Gamrie and containing similar fishes, in highly inclined strata, which are interpolated in, and completely subordinate to the great mass of Old Red Sandstone of Ross and Cromarty.*

This important observation will I trust be soon communicated to the Geological Society, for it strengthens the inference of M. Agassiz respecting the epoch during which the *Cheiracanthus* and *Cheirolepis* lived. In the mean time the phenomena at Gamrie may be explained, by supposing that the beds in which the nodules there occur, are regenerated or made up of the detritus of the adjoining Old Red Sandstone. At all events, certain species of *Cheiracanthus* and *Cheirolepis*, as above stated, belong to undisputed strata of the Old Red Sandstone, while no traces of these genera have been perceived in the Carboniferous System.

These two curious genera have not yet been found in the Old Red Sandstone of England.

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## FOSSIL SHELLS IN THE LOWEST BEDS OF THE OLD RED SANDSTONE, Pl. 3.

(See pp. 183—191.)

The shells are described by Mr. J. de C. Sowerby. Those marked * occur also in the Upper Ludlow Rock and are figured in Pl. 5., thus proving a transition from the Old Red into the Silurian System.

*Cypricardia cymbæformis*, f. 10 *a*. (*Cardites carpomorphus*, Dalm., *Act. Holm.*, 1824, p. 372. t. 4. f. 2. *Cardium carpomorphum, Hising. Petr. Suec.*, p. 63. t. 19. f. 5.) Transversely oblong, striated near the beaks, valves very deep, carinated; posterior extremity suddenly contracted into a point; beaks small, incurved, close to the anterior extremity; length 5 lines, width 11 lines, depth of each valve 4 lines.

Loc. *Felindre on the Teme, 10 miles west of Knighton.*

*Pullastra lævis*, f. 1 *a*. Transversely elongated, slightly convex, smooth, plain; anterior side small, rounded; front straight, nearly parallel with the hinge line; posterior side large, rather flattened towards the edge, which is nearly straight and oblique; length $\frac{3}{4}$ inch, width $1\frac{1}{4}$ inch.

Loc. *Horeb Chapel, in the Cwm-dwr, between Trecastle and Llandovery.*

*Cucullæa antiqua*, f. 1 *b* and 12 *a*. Transversely ovate, rather convex, smooth; posterior side largest, acutely-angular; internal lamina longitudinal; length from 3 to $4\frac{1}{4}$ lines, width from 4 to $6\frac{1}{2}$ lines.

Loc. *Horeb Chapel. Felindre on the Teme.*

*Cucullæa ovata*, f. 12 *b*. Transversely ovate, convex, even; beaks near the anterior extremity; interior lamina longitudinal, not oblique; length 9 lines, width 13 lines.

Loc. *Horeb Chapel.*

*Cucullæa Cawdori*, f. 11. Transversely elliptical, convex, posteriorly obliquely truncated; a rounded ridge extends from the nearly central beak to the posterior angle of the margin; internal laminæ oblique; length 4 lines, width 7 lines.

This shell is named after the Earl of Cawdor who found it. It ought to have been figured among the Upper Silurian fossils.

Loc. *Freshwater East, Pembrokeshire* (see p. 391).

*Arca* ———— ? Transversely oblong, very convex; muscular impressions very deep. Too imperfect to figure or to name; it is not very unlike *A. Eastnori* of the Caradoc sandstone.

*Avicula rectangularis*, f. 2. Subtriangular, very convex, approaching to carinated, smooth; anterior side nearly straight, at a right angle with the equally long hinge line; front rounded; posterior side slightly projecting in form of a large lobe; length 1 inch 2 lines, width the same.
Loc. *Horeb Chapel.*

**Leptæna lata*, figs. 10 *b* and 12 *c*. This is one of the most characteristic shells of the Upper Ludlow Rock. (see Pl. V. f. 13.)
Loc. *Felindre. Horeb Chapel.*

**Spirifer ptychodes*, f. 13. (*Delthyris Dalm. Act. Holm.*, 1827, p. 124. t. 3. f. 5; *Hising. Petr. Suec.* p. 73. t. 21. f. 8.) Slightly elongated, smooth, with 5 rounded plaits; beak of the larger valve prominent, curved; length 3½ lines, width about the same.
Loc. *Felindre. Also in Upper Ludlow Rocks.*

**Orthis lunata*, f. 12 *d.*; also in the Upper Ludlow Rock. (See Pl. 5. f. 16 and description.)
Loc. *Horeb Chapel.*

**Terebratula Nucula*, f. 1 *c* and 12 *g*. Abundant in the Upper Ludlow Rock. (See description Pl. 5. f. 20.)
Loc. *Horeb Chapel. Felindre.*

*Lingula cornea*, f. 3. Compressed, oblong, rectangular, nearly half as long again as wide; texture approaching horny; length 7 lines, width 5 lines.
Loc. *Tin Mill, Downton, Ludlow.*

*Natica glaucinoides*, f. 14. Small, globose, with a closed umbilicus: very like the *N. glaucinoides*, M.C., when young; width about 3 lines.
Loc. *Felindre.*

**Trochus helicites*, f. 1 *e* and 5. Depressed, smooth, convex beneath; whorls about 4, hardly convex above (except in the cast), obtusely angular at the margin of the base; umbilicus small and deep; width from ½ inch to nearly 1 inch.
The large specimen, f. 5, is rather more angular about the margin; f. 1 *e** shows the impression of the outer surface.
Loc. *Horeb Chapel. Also in Upper Ludlow Rock.*

*Turbo Williamsi*, f. 6. Conical, smooth; whorls convex, about 4; base convex, with a narrow umbilicus; aperture round; height 1¾ inch, width 1½ inch.[1]
Loc. *Horeb Chapel.*

*Turritella obsoleta*, f. 7 *a* and 12 *f*. Subulate, elongated, smooth; whorls 9, convex; aperture round; length 1¼ inch, width 5 lines. Variable in size; the measures given are of the largest specimen.
Loc. *Horeb Chapel. Felindre.*

*Turritella gregaria*, f. 1 *f*. Subulate, smooth, whorls 6, convex; aperture round; length 4 to 6 lines, width 2 to 3 lines. Many individuals of this *Turritella* occur together, and mostly of one size; it may nevertheless possibly be the young of the last species.
Loc. *Horeb Chapel.*

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[1] I have named this shell after my friend Mr. Williams of Llandovery, who has materially enriched this work by collecting fossils. (See p. 350.)—R. I. M.

*Turritella conica*, f. 7 *b* and 8. Conical, pointed, smooth, whorls 6, convex, rather angular; length $4\frac{1}{2}$ lines, width 2 lines. Not so frequent as *T. gregaria*.

Loc. *Horeb Chapel. Felindre.*

*Orthoceras semipartitum*, f. 9 *a*. Very slightly tapering, smooth; septa rather close, concave; siphuncle nearly central, connected with the side by a longitudinal plait; diameter 3 lines. A small species; the plate which connects the siphuncle with the side forms a fissure in the cast of each chamber.

Loc. *Horeb Chapel. Felindre.*

*Orthoceras* ———— ?, f. 12 *h*. Smooth; septa rather distant; siphon central, large. Specimen too imperfect to name.

Loc. *Horeb Chapel.*

**Orthoceras striatum.* (See Pl. 5. f. 29.) Also in the Upper Ludlow Rock.

Loc. *Horeb Chapel.*

*Orthoceras tracheale*, f. 9 *b*. Very slightly tapering, finely striated transversely; covered with obtuse, annular undulations; septa rather flat; diameter 4 lines.

Loc. *Horeb Chapel.*

*Bellerophon carinatus*, f. 4 and 1 *d*. Convoluted, compressed, keeled, smooth; inner whorls several, small, partly visible; aperture an equilateral triangle.

Loc. *Horeb Chapel.*

*Bellerophon striatus*, f. 12 *e*. Carinated, covered with sharp striæ parallel to the edge of the aperture; apex (spire ?) very small, convoluted; aperture cordate (with a narrow deep sinus in the front ?); keel flattened at the edge and transversely striated; length 6 lines, breadth 5 lines.

Loc. *Felindre.*

*Bellerophon trilobatus*, f. 16. Convoluted, smooth, 3 lobed, central lobe largest; inner whorls small, visible; aperture above twice as wide as long; length and breadth 4 lines.

Loc. *Felindre. Is the same species in the Caradoc Sandstone at Eastnor Park; north-east of Gaerfawr, Prescoed Common; and Michaelwood Chace, Tortworth?*

*Bellerophon globatus*, f. 15. (See Pl. 4. f. 50.) Globose, smooth; aperture transversely oblong, with a small sinus; width about 4 lines.

Loc. *Felindre; also in the Upper Ludlow bone bed.*

**Tentaculites scalaris*? Schlotheim. Also throughout the Silurian series. (See Caradoc sandstone, Pl. 19. f. 15.)

Loc. *Horeb Chapel. Felindre.*

### CRUSTACEA.

*Agnostus tuberculatus*, f. 17. (*Battus tuberculatus, Klöden. Verstein der Mark. Brandenb.*, p. 112. t. 1. f. 16, 17 and 18.) Semi-circular, smooth; lobes three, equal, the central one undivided.

Loc. *Lodge Bank, Downton.*

# CHAPTER XLV.

## FISHES AND SHELLS OF THE LUDLOW AND WENLOCK FORMATIONS, OR UPPER SILURIAN ROCKS.

*Fishes, &c. of the Upper Ludlow Rock,* Pl. 4.—*Shells of the Upper Ludlow Rock,* Pl. 5.—*Shells of the Aymestry Limestone,* Pl. 7.—*Shells of the Lower Ludlow Rock,* Pl. 8, 9, 10 and 11.—*Shells of the Wenlock Limestone and Shale,* Pl. 12 and 13.

1. *Fishes of the Upper Ludlow Rock.* (Pl. 4.)

SPHAGODUS, Agass.

*Sphagodus pristodontus,* Agass., Pl. 4. f. 6 and 1, 2, 3.

PTERYGOTUS, Agass.

*Pterygotus problematicus,* Agass., f. 4 and 5.

PLECTRODUS, Agass.

*Plectrodus mirabilis,* Agass., f. 14 to 26.
(Coprolites of the *Plectrodus,* f. 46, 47, &c.)

SCLERODUS, Agass.

*Sclerodus pustuliferus,* Agass., f. 27, 28, 29, 30, 31, 32, 60, 61 and 62.

THELODUS, Agass.

*Thelodus parvidens,* Agass., f. 34 and 36.

ONCHUS, Agass.

*Onchus Murchisoni,* Agass., f. 9, 10 and 11.
——— *tenuistriatus,* Agass., f. 57, 58 and 59.

THE researches of geologists have not yet made us acquainted with the existence of fossil fishes in any strata so low in the series as the Silurian rocks, and hence the forms about to be described are of great interest. They appear, in short, before naturalists, as *the most ancient beings of their class,* which have yet been brought to light.

In advancing our knowledge of fossil ichthyology, the discovery of these fishes has also confirmed the important inference drawn by M. Agassiz, from an examination of all the younger deposits; that each great formation is characterised by species peculiar to it. This doctrine is, indeed, strikingly corroborated by the evidence now produced, for of the six genera above enumerated, four are entirely new, and wholly unlike any forms in the overlying strata; while the genus *Onchus,* though known in the Carboniferous and Old Red Systems, is here composed of distinct species.

In Pl. 4. are figured all the remains which have been found in the highest stratum of the Ludlow Rocks, constituting in parts a complete "bone bed" or matted mass of scales, teeth, jaws, and

coprolites of fishes (see p. 199)[1]. The fishes have been named, and are briefly described by M. Agassiz, from drawings sent to him by myself, but more detailed descriptions of them will hereafter appear in his great work, Récherches sur les Poissons Fossiles.

"The figures 1, 2, 3," says M. Agassiz, "are very probably fragments of the skin (shagreen) of some Placoid, of which the teeth and the vertebræ are found detached in the same beds. Examine the drawing of the *Squaloraia* which I sent to the Geological Society[2], and you will perceive that the skin consists of similar tubercles, though these appear to me more pointed. They perhaps belong to the same animal of which fig. 6. represents the tooth. This tooth is sufficiently characterized to be distinguished from all those which have been already described. It constitutes a new generic type, which may be designated by the name of *Sphagodus,* (slaughtering or murderous tooth) and the species *Sphagodus pristodontus*, Agass."

"Fig. 4 and 5 belong undoubtedly to the same animal as the *Seraphim*[3] of the Old Red Sandstone. The more I know of this creature, the more I am tempted to believe that it was a fish; but how absolutely decide upon it, when we have neither discovered head nor tail, but only large wings? It may provisionally bear the name of *Pterygotus problematicus,* Agass. (wing fish)."

"Figs. 14 and 26 represent the most curious fragments of fish that have yet been discovered in the Silurian rocks. The teeth cannot be referred to any species already known, and constitute a genus, the fishes of which were without doubt the pirates of the seas of that period. The shape of these teeth, bristled with sharp points like the spurs of a cock, induce me to give it the name *Plectrodus* (cock-spur). The marked differences which your figures display in the form of the teeth, seem to indicate that this genus contains more than one species. The figures 18, 19, 22, 23, represent teeth differing sensibly from those which appear among the bones, figs. 14, 15, 16, 25 and 26, and of which figs. 20 and 21 appear to be detached teeth. Perhaps the great number of points which are visible on some of these teeth, arises from the circumstance of our seeing them on their interior or exterior surfaces. If there is but one species, it might be named *Plectrodus mirabilis,* Agass.; if there are two, that with the greatest number of points may be *Pl. pleiopristris*. The coprolites (see subsequent description) figs. 46, 47, &c. are doubtless the produce of this species, which fed on the small shells contained in those excrementitious bodies. The figs. 17 and 33 do not appear to me to differ from each other; and like figs. 1, 2 and 3, they may be the tubercles of the skin; perhaps they may have belonged to the skin of *Plectrodus*?"

"Figs. 27, 28, 29, 30, 31, 32, and 60, 61, 62, indicate another new type of tooth approaching that of the *Psammodus*, but differing from it by the raised pustules on the surface: I shall name it *Sclerodus* (rough tooth), and the species *Scl. pustuliferus*."

"Figs. 34, 35, 36 represent other teeth, approaching in some respects to those of the *Lepidotus*, of which I form a new genus *Thelodus* (mammillated tooth), and the species may be named *Th. parvidens*."

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[1] I have previously expressed my obligation to Dr. Lloyd, the Rev. T. T. Lewis, and Mr. W. Evans for their exertions in developing the fossil wealth of this curious stratum or *bone-bed,* masses of which may be seen in the museums of the Ludlow Natural History Society, and of the Geological Society of London.

[2] Now figured, Geological Transactions, vol. 5. Pl. 4.

[3] The name of *Seraphim* was given to these singular winged bodies (*Pterygotus,* Agass.) by the Scotch quarrymen, who first found them in the Old Red Sandstone of Forfarshire. On seeing specimens of them at Edinburgh, 1834, in a collection of Mr. Lyell, M. Agassiz referred them, though with some doubt, to the class of fishes.

"Figs. 40 to 45 represent rays of the fins, belonging probably to the genus *Onchus*, and which appear also to indicate another new species. Figs. 37, 38 and 39 do not appear to me determinable at present; perhaps they may be rays, or perhaps tubercles of the skin?"

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## ICHTHYODORULITES OF THE UPPER LUDLOW ROCK.

### 1. *Onchus Murchisoni*, Agass. (Pl. 4. f. 9, 10, and 11.)

"The defensive fin," observes M. Agassiz, "which I have termed *Onchus Murchisoni*, is very characteristic. Its lengthened, slender, and almost straight form, its imperceptible tapering away, the great size of the longitudinal ribs, and the depth of the alternating furrows, are traits which distinguish it at a first glance from every other species of this genus. It is very interesting (adds M. Agassiz) that your Upper Silurian Rocks should have produced a species so remarkable, and of the distinct nature of which no doubt can be entertained. The presence of three of these defences, in one small specimen which you sent me, would seem to indicate, that the species is not very rare. It is, however, to be observed, that the fishes to which they belonged, bore a spine upon each of the two dorsal fins. At all events this is the case with the living genera (*Cestracion, Centrina* and *Spinax*), with which it must be compared, though such affinity may be rather distant."

### 2. *Onchus tenuistriatus*, Agass. (Pl. 4. f. 57, 58, and 59.)

"The above-named figures best represent this species, while figs. 12 and 13 show the cavity which occurs in the posterior side of the base, and which is more or less prolonged into the interior of the spines 'rayons' of all the cartilaginous fishes with bony dorsal spines[1]. This species differs from the preceding, both in having finer and closer ribs, and in its general form, which is more arched. The rays are also proportionally shorter than those of *Onchus Murchisoni*." Extracts from letters of M. Agassiz to myself. See also Récherches, tom. iii. p. 6, since published.

### *Coprolites.*

The coprolites formerly alluded to as occurring so abundantly in this "bone bed" are represented in the figures 46, 47, 54, 55. Having submitted them to Dr. Prout, whose analysis established the views of Dr. Buckland concerning the fæcal origin of similar bodies in the lias and other formations, that distinguished chemist has favoured me with the following account of those which occur in the *bone bed* of the Ludlow rocks.

"I find all the specimens examined to consist essentially of the phosphate of lime and of the carbonate of lime. There was, however, a considerable residuum undissolved by acids, consisting apparently of silex, oxide of iron, together with carbonaceous and other matters, the nature of which was not ascertained.

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[1] For an account of the proof that the dorsal spines of cartilaginous fishes have a bony structure, see structure of ichthyodorulites in preceding Chapter.

"From these and other circumstances to be presently mentioned, and from their mechanical structure, there can, I think, be little doubt that the masses in question are really coprolites. I confess, however, that I should hardly have arrived at this conclusion, had I not before repeatedly examined coprolites, and witnessed the variety to which they are liable.

"I have alluded above to certain other circumstances corroborative of the opinion advanced. These relate to the *origin* of the principal materials of which our 'supposed coprolites' are composed, and may in conclusion be briefly stated.

"The mass of the bed, containing these concretions, consists almost entirely of a congeries of various organic remains. Of these organic remains, two kinds strikingly predominate. One kind, and by much the most abundant, consists of fragments of bones (scales or spines), for the most part of a dark or black colour. The other kind of organic remains differs altogether in texture and appearance from the black fragments, and is of a reddish brown colour. The black organic fragments I find to consist of phosphate of lime and of carbonate of lime; and there is left, undissolved in the acid employed, some carbonaceous and other matters. The reddish brown fragments consist also of carbonate of lime and phosphate of lime, but the phosphate of lime appears to be in much less proportion than in the black fragments. The composition, therefore, of these organic remains seems to account very satisfactorily for the *origin* of the phosphate and carbonate of lime in the 'supposed coprolites.'"—*Letter from Dr. Prout.*

The small shells (*Orbicula rugata*, f. 47 and 48; *Lingula minima*, f. 49; *Bellerophon globatus?* f. 50; *Turritella*, f. 51; and *Orthoceras semipartitum*, f. 52 and 53.), as well as the cast of a crinoidal column, f. 54, were found both in the coprolites and diffused through the layers.

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## FOSSIL SHELLS OF THE UPPER LUDLOW ROCK.

Described by Mr. James de C. Sowerby.

PLATE V.

*Serpulites longissimus*, f. 1.[1] Very long, hardly diminishing in diameter, compressed, smooth, slightly tortuous, composed of numerous thin layers of shell containing much animal matter.

No part of this extraordinary fossil has been observed attached to other bodies; it forms large curves, sometimes almost circles, occasionally even a foot in diameter. The tube is so much compressed that its sides nearly touch, and that this is the effect of pressure is shown by the form it has assumed. Those parts which were nearly perpendicular to the direction of the compressing force have resisted pressure most powerfully, and fractures have taken place in longitudinal lines near such parts. The quantity of animal matter in the laminæ gives them an opalescent appearance. In structure, this fossil resembles the *Serpula compressa of Min. Con.*, tab. 598. f. 3; but it does not diminish so rapidly. Width ½ an inch.

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[1] In the description of the Upper Ludlow Rock this fossil has been inadvertently named *Serpuloides longissima*.

No naturalist who has examined this form has been able to throw any light upon its true place in the animal kingdom, and I have therefore named it provisionally *Serpulites longissimus*.—R. I. M.

Loc. *Ludlow, very abundant; Kington, Herefordshire; and very generally throughout the Upper Ludlow Rock of Salop, Hereford, Radnor, &c.*

*Cypricardia? amygdalina*, f. 2. Transversely ovate, elongated, obtusely keeled, smooth; posterior extremity pointed; hinge line straight; beaks short, very near to the anterior extremity; valves deep. Frequently much distorted by pressure. Length $1\frac{1}{4}$ inch, width $\frac{1}{2}$ inch.

Loc. *Abundant in the Ludlow promontory, and very generally characteristic of the Upper Ludlow Rock.*

*Cypricardia? impressa*, f. 3. Transversely oblong, smooth; anterior extremity slightly truncated, the other pointed obtusely; front concave; hinge line straight, long; beaks near the anterior extremity. Variable in size. Very much like the last, but more rounded, and further distinguished by the depression along the middle. Length 7 lines, width 1 inch 3 lines.

Loc. *Delbury near Ludlow.*

*Cypricardia? undata*, f. 4. Transversely elongated, very convex; surface largely undulated; front concave; beaks short, close to the anterior extremity; lunette heart-shaped. Length $\frac{1}{2}$ an inch, width 1 inch.

Loc. *Near Aymestry.*

*Cypricardia? retusa*, f. 5. Heart-shaped; anterior extremity rather pointed, and separated from the other parts by a concave space; beaks large. Length 5 lines, width 8 lines.

Loc. *Delbury.*

*Cypricardia cymbæformis*, var., f. 6. (*Cardites carpomorphus? Dalm. Act. Holm.* 1824., p. 372. t. iv. f. 2; *Cardium carpomorphum? Hisinger Petr. Suec.*, 63. t. xix. f. 5.) Transversely oblong; valves deep, carinated; the keel acute, extending from the beak to the angular extremity of the narrow, oblique, produced posterior side; beaks short, incurved, close to the small heart-shaped anterior side. Length 7 lines, width 1 inch 4 lines.

This differs from *C. cymbæformis* of the Old Red Sandstone in being less inflated and rather wider. Both are much less triangular and shorter in proportion than *Cardites carpomorphus* of Dalman, of which, however, we have only seen the figure. *Serpulites longissimus?*, *Cucullæa antiqua*, *Leptæna lata*, and *Bellerophon expansus* occur in the same mass with the specimen before us.

Loc. *Ludlow.*

*Pullastra complanata*, f. 7. Transversely elongated, twice as wide as long, smooth, rather flat; anterior extremity small, rounded; posterior extremity pointed, its edge oblique; beaks not prominent, very near the anterior extremity. Length $\frac{3}{4}$ inch, width $1\frac{1}{2}$ inch.

This differs from *P. lævis* of the Old Red Sandstone chiefly in the angular form of the posterior margin.

Loc. *Darley Brook, Linley, near Bridgenorth; rare.*

* *Cucullæa antiqua.* (See Pl. 3. f. 1 *b*.)

Loc. *Ludlow.*

*Nucula? ovalis*, f. 8. Transversely oval, rather convex; beaks pointed, near the anterior side. Length nearly 4 lines, width 5 lines.

Not having been able to clear the stone from the hinge of the only specimen obtained of this fossil, which is a cast of the interior, the genus remains doubtful.

Loc. *Trewerne Hills on the Wye, Radnorshire.*

*Avicula retroflexa?* f. 9. (*Hisinger. Act. Holm.* 1826. t. vii. f. 9; *Petr. Suec.* 57. t. xvii. f. 12.)

Semicircular, two-lobed, oblique, rather convex, transversely wrinkled; anterior lobe very small. Length 10 lines, width $1\frac{3}{4}$ inch.

Hisinger refers this species to the lias and lower oolite. If this be correct, our species cannot be the same as that of Hisinger.

Loc. *Hale End, Malverns; and near Usk.*

*Avicula lineata*, f. 10. Obliquely ovate, flattened, ornamented with many radiating elevated lines; anterior lobe minute, the posterior ear distinct, triangular, half as long as the posterior slope. Length 9 lines, width 1 inch 2 lines.

Loc. *Ludlow.*

*Orbicula rugata*, f. 11. Nearly orbicular; upper valve a very low oblique cone with a concentrically wrinkled surface; lower valve nearly flat. Diameter 6 lines, height 2 lines.

Loc. *Ludlow promontory, viz. Richards Castle, &c.; Delbury; Bradnor Hill, Kington; Bagbarrow Hill; Pains Castle, Radnorshire. Very abundant.*

*Orbicula striata*, f. 12. Orbicular, convex, covered with minutely radiating striæ; apex deflected, marginal. Diameter 7 lines, height 3 lines.

One specimen is attached to the septum of an *Orthoceras.*

Loc. *Delbury, and Ludlow Hills.*

**Leptæna lata*, f. 13. (*Von Buch; Producta*, Sow.) Semicircular, the front rather straight; upper valve convex, the middle a little depressed; lower one concave; surface covered with fine radiating ridges; hinge line straight, furnished with 8 or 10 long divaricating spines. Length half the breadth.

The spines in all the specimens we have seen are simple tubes, not jointed as they are figured and described by Baron Von Buch, who must have had much better specimens than occur in England.

Loc. *Ludlow promontory; Delbury, and the range of Mogg Forest, Munslow, &c.; Presteign; Stoke Edith; Fownhope, and outer band of Woolhope Valley; Bradnor Hill; near Kington; near Usk; Bagbarrow Hill; North of Barrow; near Newnham; in the Brecon anticlinal. Characteristic and most abundant.*

*Atrypa didyma*, Dalm. (See Pl. 6. f. 4.) Also Aymestry Limestone.

Loc. *Fownhope; Dog Hill, Ledbury.*

*Atrypa affinis.* (*Min. Conch.* t. 324. f. 2.) (See Pl. 6. f. 5.) Also in Aymestry Limestone and throughout the Upper Silurian Rocks.

Loc. *Ludlow; Aymestry, and many localities.*

*Spirifer crispus.* (See Pl. 12. f. 8.) Also Wenlock Limestone.

Loc. *Abberley; Freshwater east, Pembrokeshire.*

**Spirifer ptychodes.* (*Delthyris ptychodes, Dalm. Act. Holm.* 1827. p. 124. t. iii. f. 5.; *Hisinger Petr. Suec.* p. 73. t. xxi. f. 8.) (See Pl. 3. f. 13.) Also Old Red Sandstone.

Loc. *Abberley; Bradnor Hill; near Kington; Fownhope.*

*Spirifer trapezoidalis*, f. 14. (*Cyrtia trapezoidalis, Dalm. Act. Holm.* 1827. p. 119. t. cxi. f. 2; *His. Pet. Suec.* p. 72. t. xxi. f. 1; *Von Buch.* Pl. 1. f. 15 and 16.) Nearly semicircular, transverse longitudinally striated: a rounded elevated ridge extends from the beak to the front of the upper valve with a corresponding furrow in the other valve; hinge line rather shorter than the diameter of the shell, the extremities rounded; area large, curved; the foramen narrow.

Loc. *Usk; Craig-y-garcyd.* (*Iron Bridge, Coalbrook dale, Von Buch.*)

N.B. This fossil has been figured in this plate inadvertently, for it does not belong to the Upper Ludlow, but rather to the Lower Ludlow and Wenlock strata.

*Orthis lunata*, f. 15. Transversely obovate; finely and deeply striated; valves almost equally convex; the lesser with a slight depression along the middle; beaks not very prominent, and within it has two semicircular ridges; area of the hinge small. Length 5 lines, width 7 lines.

Loc. *Ludlow; Delbury; of very frequent occurrence; also in the lowest beds of Old Red Sandstone.*

*Orthis orbicularis*, f. 16. Obovate, approaching to orbicular; finely and deeply striated; the larger valve very convex, with a slighly curved beak, within which is a straight longitudinal ridge, with a curved one on each side of it (seen best in the impressions they leave in the cast); the other valve slightly convex with a wide depression along the middle; area of the hinge very small. Length 6 lines, width 7 lines.

Loc. *Ludlow; Delbury; Sutton, near Wenlock; Dog Hill, near Ledbury; Cwm-nant-gwyn, near Builth.*

These two species of *Orthis* are so nearly alike, that it is often impossible to determine to which the specimen under examination may belong, unless it be very perfect, or show the impressions upon the cast of the characteristic ridges in the interior. One or both species occur with *Leptæna lata* and *Terebratula Nucula* in numberless localities near Ludlow, Munslow, Aymestry, Presteign, Knighton, Kington, Builth, Brecon (the Corn-y-fan, or Brecon anticlinal), Usk, Sedgeley, Abberley and Ledbury.

*Terebratula Navicula*, f. 17. Oblong, boat-shaped, smooth; the upper valve nearly flat, its sides elevated, the front depressed; the lower valve obtusely keeled, its beak short, incurved: f. 17 *a* represents the cast of the interior. Length 7 lines, width 5 lines.

Loc. *Ludlow promontory; Clyro Hills, Radnorshire; Brecon anticlinal, viz., Corn-y-fan; Alltfawr and Rhiwannest, abundant, at the base of the Upper Ludlow.*

*Terebratula canalis*, f. 18. Elliptical, smooth, with a narrow longitudinal furrow; front emarginate; beak incurved. Length ½ an inch, width 4½ lines.

Our description of this is necessarily meagre, because we have only seen one valve. The fossil belongs rather to the Lower Ludlow.

Loc. *Near Usk.*

*Terebratula lacunosa*, f. 19. (*Anomia lacunosa, Linn.; Gmel.* t. i. 3343. *Terebratulites lacunosus, var. Schlotheim, Nachtrage, zur Petrefact.* p. 68. t. 20. f. 6; *Ter. borealis, Von Buch. loc. cit.* p. 67; *von Hisinger.*) Obovate, gibbose, obscurely 3 lobed, acutely plaited; plaits about 16, 4 or 5 of which in the middle of the front are much elevated; beak small, pointed, slightly incurved. Length 7 lines, width 8 lines.

This is one of the least lobed varieties of *T. lacunosa*, if it be a variety of that species; the specimens before us are not complete enough to determine a question so difficult in this section of the family of *Terebratulæ*.

Loc. *Ludlow promontory and Delbury, Salop; Aram, near Newnham; Trewerne Hills; the Maund, Abbereddw, and Pain's Castle, Radnorshire; Abberley Hills.*

**Terebratula Nucula*, f. 20. Globose, obscurely 3 lobed, plaited; plaits sharp, about 15, 3 or 4 of which are prominent and elevated in the middle of the front; beak small, adpressed; lower valve slightly flattened. Length 5 lines, width the same.

Loc. *Ludlow; Delbury; Presteign; Ledbury; Bagbarrow Hill; and west of Malvern*

*Hills; Abberley; Bradnor Hill, Kington; Trewerne Hills, Radnorshire; Aram, near Newnham: abundant.*

*Terebratula pulchra*, f. 21. Globose, rather triangular, obscurely 3 lobed, plaited; plaits sharp, about 20, 5 of which are elevated in the front; beak small, projecting.

This resembles the last, but is more angular, and has smaller and sharper plaits, which make it peculiarly elegant, while *T. Nucula* is rather clumsy in its appearance. Length 4 lines, width the same.

Loc. *Delbury; Bagbarrow Hill; Malverns.*

*Terebratula pentagona*, f. 22. Pentagonal, wider than long, depressed, obscurely 3 lobed, plaited; plaits about 25, rounded, not extending to the beaks, 9 or 10 of the central ones raised at the front; beak very small. Length 6 lines, width $6\frac{1}{2}$ lines.

Loc. *Delbury, Salop.*

*Lingula minima*, f. 23. Oblong, elongated, with parallel sides, flat, smooth and thin. Length 4 lines, width $2\frac{1}{2}$ lines.

The species of *Lingula* so nearly resemble each other, that it is difficult to distinguish them by words. This specimen may be the young of some other species.

Loc. *Delbury; Downton Castle.*

*Natica parva*, f. 24. Sub-hemispherical, smooth; spire flat, of little more than one whorl; aperture semicircular, very large. Greatest diameter $4\frac{1}{2}$ lines, height 3 lines.

Loc. *Fownhope; in the outer band or Ludlow Rock of the Woolhope Valley.*

*Pleurotoma articulata*, f. 25. Turretted, nearly smooth, being only marked with sharp lines of growth; whorls 8 or 10, very convex; sinus nearly in the middle of the whorl, forming a broadish band. The whorls are so round and distinct as to give the spire a jointed appearance like a row of beads. Length $10\frac{1}{2}$ lines, width $3\frac{1}{2}$ lines.

Loc. *Ludlow, and near Ledbury.*

*Pleurotoma corallii*, f. 26. Turretted, smooth; whorls 8 or 10, convex; lines of growth indistinct; sinus below the middle of the whorl forming a narrow band. Length $6\frac{1}{2}$ lines, width 3 lines.

Loc. *Ludlow promontory; Larden; Fownhope; Botteville, north side of Caer Caradoc; Aram, near Newnham; north-east of Gaerfawr (generally enveloped in coral); Bradnor Hill, Kington.*

*Trochus helicites*. (See Pl. 3. f. 1 *e* and 5.) Also Old Red Sandstone.

Loc. *Ludford; Ludlow.*

*Turbo corallii*, f. 27. Conical, acute, covered with sharp spiral lines; whorls about 6, rounded; aperture orbicular; umbilicus closed. Length $\frac{1}{2}$ an inch, width 4 lines.

Loc. *Larden; near Ludlow; Trewerne Hills, Radnorshire; Aram; near Newnham, Glostershire (in all these distant places enveloped in the same coral,* Favosites fibrosa, *Goldfuss*).

*Turbo carinatus*, f. 28. Conical, acute, ornamented with several spiral sharp carinæ, and longitudinally striated; aperture orbicular; umbilicus closed. Three of the carinæ are visible upon each whorl. Length $\frac{1}{2}$ an inch, width 5 lines.

Loc. *Ludlow promontory; Trewerne Hills; generally imbedded in coral like the last.*

*Orthoceras striatum*, f. 29. (*Min. Conch.* t. 58.) Gradually tapering, finely and regularly striated longitudinally; septa very close, deep; siphuncle central, rather large, nearly cylindrical. Length 9 inches or more, width 2 to 3 inches.

Loc. *Ludlow; Brecon anticlinal; Tortworth (generally compressed).*

*Orthoceras virgatum.* (See Pl. 9. f. 4.) Also Lower Ludlow Rock.

Loc. *Bagbarrow Hill (Malverns).*

*Orthoceras Ibex,* f. 30. (*Orthoceratites annulatus, Hisinger Petr. Suec.* 29. t. ix. f. 8.; *not of Min. Con.*) Very gradually and irregularly tapering, compressed, smooth; surface elevated in oblique rings, one fourth their diameter apart. Length of the fragment about $2\frac{3}{4}$ inches, width 8 lines.

Loc. *Ludlow.*

*Orthoceras articulatum,* f. 31. Very gradually tapering, compressed, smooth; surface elevated in oblique rings, one third their diameter apart. Length of the fragment about 2 inches, width $\frac{1}{2}$ an inch.

Loc. *Ludlow promontory; east of Aymestry; near Ledbury; occurs also in Lower Ludlow Rock.*

It appears probable that these two fossils are straight portions of *Lituites,* the *O. articulatum* being a portion of *Lituites articulatus.*

*Cyrtoceras* (Goldfuss) *læve.* (See Pl. 8. f. 21.) Also Lower Ludlow.

Loc. *Ludlow.*

*Bellerophon expansus,* f. 32. Spire small, rounded; aperture very large, two lobed, twice as long as broad; sinus broad and short. Length of the aperture $7\frac{1}{2}$ lines, width of ditto 11 lines.

Loc. *Ludlow; Trewerne Hills.*

**Bellerophon globatus.* (See Pl. 3. f. 15. and Pl. 4. f. 50.) Base of Old Red Sandstone and Ludlow *bone-bed.*

The figure in Pl. 4. is taken from a cast contained in Coprolites.

Loc. *Ludford; Ludlow.*

**Bellerophon carinatus.* (Pl. 3. f. 4 and 1 *d.*) Also Old Red Sandstone.

Loc. *Bradnor Hill.*

**Tentaculites scalaris.* (See Pl. 19. f. 15.) (*Schlotheim Petrefact.* t. 29. f. 9 *b.*) Also Caradoc Sandstone.

Loc. *Delbury; Bradnor Hill; Fownhope.*

*Tentaculites tenuis,* f. 33. Subulate, pointed, very narrow, with numerous slender elevated rings upon the surface. Width of the aperture $\frac{1}{2}$ a line.

More slender in form, and with closer rings, otherwise much resembling *T. annulatus,* Pl. 19. f. 16.

Loc. *Near Usk in the same mass with Terebratula canalis,* f. 18.

N.B. The shells marked with an asterisk occur also in the Tilestones or lowest beds of the Old Red Sandstone, and mark the transition from the Old Red into the Silurian System.

*Spirifer trapezoidalis, Terebratula canalis, Tentaculites tenuis, Cornulites serpularius, and Cyrtoceras læve,* are not fossils of the Upper Ludlow but rather of the Lower Ludlow and Wenlock strata.

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## SHELLS OF THE AYMESTRY LIMESTONE OR MIDDLE LUDLOW ROCK.

### PLATE VI.

*Mya rotundata,* f. 1. Transversely elongated, convex and wrinkled; beaks near the anterior por-

tion, which is separated by a slightly concave space from the middle of the shell. Length 11 lines, width 1 inch 5 lines.

Distinguished from *Cypricardia undata* (Pl. 5. f. 4.) by the want of a lunette.

Loc. *Caynham Camp near Ludlow.*

*Cardium? striatum*, f. 2. Orbicular, convex, longitudinally striated; striæ numerous; beaks prominent. Length 1 inch 10 lines, width the same.

Loc. *Aymestry; also near Shelderton in Lower Ludlow.*

*Cardium? striatum*, var. Larger than the above, and rather oblique in form and furnished with more distant and deeper striæ.

Loc. *From the landslip in Wheeler Vallets Wood, north flank of Bringdwood Chace.*

*Avicula reticulata?* f. 3. (*Hisinger Petr. Suec.* 57. t. xvii. f. 13?) Ovate, broad, pointed towards the beaks, rather convex, ribbed; ribs numerous, decussated by the lines of growth; one valve nearly flat; ears unequal, one very large, right-angled. Length 2 inches, width 1 inch 8 lines.

Loc. *Croft Valley; Aymestry.*

*Leptæna euglypha. Productus euglyphus, passim.* (See Pl. 12. f. 1.) Also Wenlock Limestone.

Loc. *Mocktree; Aymestry.*

*Leptæna depressa. Productus depressus, passim.* (See Pl. 12. f. 2.) More prevalent in Wenlock Limestone.

Loc. *Mocktree Forest.*

*Atrypa didyma*, f. 4. (*Ter. didyma, Dalm. Act. Holm.* 1827. p. 146. t. 6. f. 7; *Hisinger Pet. Suec.* p. 77. t. xxii. f. 7.) Nearly globose; beaks small; front emarginate, with a furrow in each valve reaching nearly to the beaks. Length 5 lines, width the same.

This is often found inclosed in *Ter.? Wilsoni*, and sometimes a pair of *T. Wilsoni* inclosing one of this is contained in another of *T. Wilsoni.* (See f. 7*b*.)

Loc. *Wallsgrove Quarry; Sunny Hill Bank, Ludlow; and also in Upper Ludlow Rock.* (*Pretty abundant.*)

*Atrypa affinis*, f. 5. (*Ter. affinis, Min. Con.* t. 324. f. 2; *Atrypa reticularis, Dalm. Act. Holm.* 1827. p. 127. t. 4. f. 2; *Hisinger Petr. Suec.* 75. t. xxi. f. 11; *Ter. priscus, Schl.* t. 17. f. 2; *Von Buch. Terebrat.* p. 71.)

Loc. *Very abundant in the Aymestry Limestone and throughout the Upper Silurian Rocks.*

*Atrypa aspera* (Schlot.). (See Pl. 12. f. 5.) Also Wenlock Limestone.

Loc. *Churnbank or Palmer's Cairn, and other parts of Ludlow promontory.*

*Spirifer crispus.* (*Delthyris crispa, Dalm. loc. cit.* p. 122. t. 3. f. 6; *S. octoplicatus, M. C.* t. 562. f. 4.) (See Pl. 12. f. 8.) Also Wenlock Limestone.

Loc. *Sunny Hill Bank near Ludlow.*

*Spirifer interlineatus*, f. 6. Transversely oval, convex, finely striated longitudinally, ribbed; ribs all rounded, 5 on each side, a large elevated one in the middle; beak of the larger valve produced, and then so much incurved as to meet the beak of the other valve. Length 5½ lines, width 6½ lines.

Loc. *Aymestry; also in Wenlock Limestone.*

*Orthis Pecten*, var.? Transversely obovate, flat with numerous sharp radiating sulci increasing in number towards the margin. Length 10½ lines, width 1 inch 4 lines.

A much wider shell than the true *O. Pecten*. Specimen only one imperfect valve.

Loc. *Aymestry.*

*Orthis orbicularis.* (See Pl. 5. f. 16.) Also Upper Ludlow Rock.

Loc. *Botville, near Church Stretton.*

*Terebratula Wilsoni,* f. 7 *a.* (*M. C.* t. 118. f. 3; *Ter. lacunosa, Wahl. Dalm. loc. cit.* p. 139. t. 6. f. 1; *Hisinger Petr. Suec.* 80. t. xxiii. f. 3, not Linn.; *Ter. Wilsoni, Von Buch, Terebr.* p. 47.) The form of the shell, approaching to cylindrical, and the long furrows upon the front sufficiently distinguish this species.

Loc. *Aymestry.* This shell is highly characteristic of the central beds of the Ludlow formation and is of very constant occurrence in Salop, Hereford, Radnor, &c.

*Terebratula Nucula.* (See Pl. 5. f. 20.) Also Upper Ludlow Rock.

Loc. *Aymestry, Ludlow, Sutton; Bottville, Caradoc.*

*Terebratula Navicula.* (See Pl. 5. f. 17.) Also in the lowest bed of the Upper Ludlow Rock.

These three species of *Terebratula* often mark the place of the Aymestry Limestone, as in the Brecon anticlinal, the valley of Woolhope, at Usk, &c.

Loc. *Aymestry, Ludlow, Yeo Edge, and in numerous places.*

*Pentamerus Knightii,* f. 8 *a, b, c.* (*Min. Con.* t. 28; *Uncites Gryphoides, Defr., Ter. Gryphus, Von Buch,* p. 69; *Gypidia Conchidium, Linn. Mus. Tessin.* p. 90. t. 5. f. 8; *Dalm. loc. cit.* p. 125. t. 4. f. 1; *Hisinger Petr. Suec.* 711. t. xxi. f. 10; *Anomia bilocularis*; *Hisinger Act. Holm.* 1798. p. 285.) After the examination of a great number of specimens it has been ascertained that the lesser valve varies much in convexity, and hence that *P. Aylesfordii, Min. Con.* t. 29, is not a distinct species. (See f. 8 *c.*)

The *Pentamerus Knightii* presents the peculiar organization by which the genus is marked in a high degree of perfection; the lesser valve being divided internally by two longitudinal, parallel, approximate septa, and the other valve by one large, also longitudinal, septum, which is forked towards the beak. These septa are composed of short fibres which meet in the middle, so that each septum is easily divided into two. Owing to this structure and to its usually being filled with subcrystalline carbonate of lime, this fossil, though sometimes entire, frequently splits into two parts, one containing two and the other three of the chambers formed by the septa: commonly also, a small piece separates from within the forked part of the large septum near the beak. (See f. 8 *b.*)

The *Pentamerus Knightii* may be seen in this state all along the escarpments of the Ludlow formation, extending from Aymestry to the View Edge west of Ludlow. Throughout that district and at Sedgeley near Dudley, this species of *Pentamerus* is *peculiar to the Aymestry Limestone,* though one example of it has been observed (by Mr. Davies of Presteign) in the equivalent of the Wenlock Limestone near Presteign. (See p. 313.)

The name of Mr. Thomas Andrew Knight, F.R.S., President of the Horticultural Society of London, in whose beautiful demesne of Downton Castle it is found abundantly, has been with great propriety attached to this curious and characteristic fossil.

Loc. *Aymestry; Downton on the Rock; Yeo Edge; and Sedgeley, Staffordshire.*

*Lingula Lewisii,* f. 9. Oblong, compressed, smooth; sides straight and parallel. Length 1 inch 2 lines, width $9\frac{1}{2}$ lines. The squareness of the outline produced by the straight sides is characteristic.

Loc. *Aymestry and many situations in the Ludlow promontory, viz. Mary Knoll, Sunny Bank, Palmer's Cairn; also at Abberley and at Sedgeley; very characteristic.*

This large and beautiful species, of which the shell is generally well preserved and often of a blue colour, is named after the Rev. T. T. Lewis of Aymestry.

*Pileopsis vetustis.* The aperture of the only imperfect specimen yet obtained from the Aymestry Limestone, appears less expanded than in the *Pileopsis vetusta* of the Carboniferous Limestone. (*Min. Con.* t. 607.)

Loc. *Aymestry.*

*Euomphalus funatus.* (*Min. Con.* t. 450; *Hisinger Petr. Suec.* 37. t. xi. f. 11.) (See Pl. 11. f. 20.) Also Wenlock Limestone.

Loc. *Walls Grove Quarry, Aymestry; Usk.*

*Euomphalus carinatus,* f. 10. (Is this *Inachus sulcatus, Hisinger Petr. Suec.* 38. t. xii. f. 1?) Nearly discoid, with a broad sharp keel around the margin; umbilicated; whorls few, convex, marked with many small concentric ridges crossed by sharp lines of growth; aperture ovate, longer than wide. Diameter nearly 3 inches.

Loc. *Aymestry; also in the Wenlock Formation, at Delves Green, Wallsall.*

*Pleurotoma corallii.* (See Pl. 5. f. 26.) Also Upper Ludlow Rock.

Loc. *Aymestry; Botville, Caradoc; Fownhope.*

*Turbo corallii.* (See Pl. 5. f. 27.) Also Upper Ludlow Rock.

Loc. *Fownhope; Aymestry; Botville, Caradoc.*

*Orthoceras Mocktreensis,* f. 11. Gradually tapering; lines of growth distinct; septa rather distant; siphuncle large, spherically inflated between each septum. Diameter 1 inch.

It is difficult to distinguish the species of *Orthoceras* from such specimens as the one figured. Though somewhat resembling it in form, this fossil is of less size than *O. giganteum, Min. Con.* t. 246. The specimen figured is remarkable for being half filled with chert and half with calc spar; the surface is siliceous, and has remarkable lines of growth, indicating a break in the shell. The name is provisionally adopted.

Loc. *Mocktree Hays; Abberley.*

*Orthoceras pyriforme.* (See Pl. 8. f. 19 and 20.) Also Lower Ludlow Rock.

Loc. *Aymestry (specimen small).*

*Orthoceras virgatum.* (See Pl. 9. f. 4.) Also Lower Ludlow Rock.

Loc. *Abberley.*

*Bellerophon Aymestriensis,* f. 12. Thick, discoid, with a broad, rather flat, margin; whorls few, their section transversely oblong and but slightly indented by the preceding whorl; aperture expanded. The greater part of the mouth is, in this specimen, broken away, but enough is left to show that it expands: is it not possible that if it were perfect it would prove to be like *B. dilatatus,* (Pl. 12. f. 23 and 24)? Diameter 3¼ inches, thickness 2 inches 10 lines.

Loc. *Aymestry.*

*Bellerophon* ——. Somewhat resembling *B. tenuifascia, Min. Con.* t. 470., but too imperfect to name.

Loc. *Westwood Common.*

N.B. Several of the above fossils occur in the beds of the Upper and Lower Ludlow Rock, immediately above and below the Aymestry Limestone.

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## FOSSILS OF THE LOWER LUDLOW ROCK.

### PLATE VIII., IX., X. AND XI.

*Spirorbis tenuis,* Pl. 8. f. 1. Whorls about 2, dextral; diameter about 1 line.

Many individuals of this shell, too imperfect to be described, are imbedded in the matrix which filled the interior of a *Phragmoceras* and are accompanied by a coralline. Little more than the surfaces by which they were attached is distinguishable, and viewing them thus, the whorls appear to be sinistral. The name expresses the thinness of the shell.

Loc. *Leintwardine near Ludlow.*

*Cypricardia solenoides,* Pl. 8. f. 2. Subcylindrical, a little compressed; beaks near to the small, rounded, anterior extremity; posterior extremity flattened and truncated at the edge; lunette large and deep. Length $5\frac{1}{2}$ lines, width $11\frac{1}{2}$ lines.

Some specimens of *C. amygdalina* approach near to this species, but the fossils referred to this genus throughout the Upper Silurian Rocks are often so much distorted by pressure that it is difficult to distinguish their original form.

Loc. *Ludlow escarpments; Abberley.*

*Psammobia rigida,* Pl. 8. f. 3. Subcylindrical, three times as wide as long; surface raised in 10 or 12 sharp undulations; anterior side slightly attenuated; the posterior truncated; beaks rather nearest to the former; base straight. Length $3\frac{1}{2}$ lines, width about 9 lines.

A small shell, the specimen is not perfect, but shows indications of 3 ridges diverging from the beaks over the posterior side.

Loc. *Garden House near Aymestry.*

*Cardium striatum.* (See Pl. 6. f. 2.) Also Aymestry Limestone.

Loc. *Shelderton.*

Cardiola (*Broderip*). Gen. Char. "An oblique, equal-valved, unequal-sided bivalve; beaks prominent and curved; surface concentrically furrowed; hinge line long, with a flat area."

Not being able to refer the two following fossils to any established genus, Mr. Broderip proposed a new one for them. He has not, however, had access to those parts which are required for clear generic distinctions, and was obliged to confine himself to an indication of the general contour. These shells are very characteristic of the *lower* members of the Upper Silurian Rocks over very wide tracts.

*Cardiola fibrosa,* Pl. 8. f. 4. Cordiform, longitudinally striated; striæ numerous, fine; beaks elongated, sharp; concentric furrows about 9. Length 11 lines, width about 10 lines.

The absence of the longitudinal striæ upon the zones near the beak may be due to the fossils being casts of the internal surface of the shell.

Loc. *Mary Knoll Dingle, near Ludlow; Long Mountain, near Welch Pool; Flagstone Quarries of Yechad, Montgomeryshire; Radnor Forest, &c.*

*Cardiola interrupta,* Pl. 8. f. 5. (*Cardium cornu-copiæ*[1], *Goldfuss,* t. 143. f. 1.) Cordato-ovate, rather compressed; surface marked with many diverging furrows which are not so deep as the less numerous concentric ones; beaks short. Length 11 lines, width the same.

Loc. *Garden House Quarry near Aymestry; Breidden Hills; Long Mountain and Railth near Welch Pool; Water-break-its-neck, Radnor Forest; Cwm-craig-dhu, Myniddepynt, Brecknockshire.*

*Modiola? semisulcata,* Pl. 8. f. 6. Transversely ovate, convex, imperfectly 2 lobed; anterior lobe

[1] The *Cardium cornu-copiæ, Goldfuss,* is the *Cardiola interrupta* of the Lower Ludlow. Our name was adopted and printed (see Geol. Proc. vol. ii. p. 13. Jan. 1834.) four years before the last fasciculus of the work of Goldfuss was published. Although describing it as a *Cardium,* Goldfuss allows that he refers it with uncertainty to that genus.—R. I. M.

much smallest, transversely furrowed, furrows extending into the middle of the shell; beaks prominent, near the anterior extremity. Length 2 inches, width 1 inch.

A portion of the anterior extremity of the most perfect specimen of this shell being wanting, we are quite uncertain of the genus; very probably it does not belong to *Modiola*.

Loc. *Shelderton Hill; and near Aymestry.*

*Avicula reticulata.* Also Aymestry Limestone. (See Pl. 6. f. 3.) Casts in a soft ferruginous stone.

Loc. *Myddleton Hall, Caermarthenshire.*

*Leptæna Lepisma* (*Dalm.?*), Pl. 8. f. 7. Semicircular, convex, shining, with a few obscure slightly elevated forked rays; hinge line equal to the width; front moderately deflected. Length about 3 lines, width $5\frac{1}{2}$ lines.

A pretty shell with a satin-like tissue; a few punctures in the substance give obscure indications of minute spines.

Loc. *Near Clungunford.*

*Leptæna euglypha. Productus euglyphus.* (See Pl. 12. f. 1.) More frequent in Wenlock Limestone.

Loc. *Eastnor Park*; *Myddleton Hall, Caermarthenshire.*

*Leptæna depressa. Productus depressus.* (See Pl. 12. f. 2.) More frequent in Wenlock Limestone.

Loc. *Abberley; the Hayes, Dudley; Myddleton Hall, with L. euglypha, &c.*

*Orthis orbicularis?* (See Pl. 5. f. 16.) Also Upper Ludlow Rock.

Loc. *Myddleton Hall; Oldcastle, Malverns; Abberley; near Aymestry.*

*Atrypa obovata,* Pl. 8. f. 8 and 9. Transversely obovate; convex, smooth; beaks small, close; front with a marginal elevation in one valve, forming a rounded sinus in the edge of the other. Length 5 lines, width $5\frac{1}{2}$ lines.

Loc. *Mathon Lodge; west flank of the Malvern Hills.*

*Atrypa didyma* (*Dalm.*). (See Pl. 6. f. 4.) Also Aymestry Limestone, &c.

Loc. *Shelderton Hill, Ludlow.*

*Atrypa galeata,* (*Dalm.*), Pl. 8. f. 10. (See Pl. 12. f. 4.) Also Wenlock Limestone. The section figured here shows the internal septa, which are not so well seen in the specimens from the Wenlock Limestone.

Loc. *Ludlow escarpments; Stumps Hill; Eastnor Park; Oldbury Camp; Westwood Common; Pendle beds, Aymestry* (*Sitch Wood, Ledbury*).

*Atrypa affinis.* (*M. C.* 324.) (See Pl. 6. f. 5.) More frequent in Aymestry Limestone, &c.

Loc. *Myddleton Hall; Turner's Hill, Dudley.*

*Atrypa aspera* (*Scloth.*). (See Pl. 12. f. 5.) Also Wenlock Limestone.

Loc. *West flank of Malverns.*

*Spirifer radiatus.* (*M. C.* 493.) (See Pl. 12. f. 6.) Also Wenlock Limestone.

Loc. *West flank of Malverns; Myddleton Hall.*

*Spirifer trapezoidalis?* (*Dalm.*) (See Pl. 5. f. 14.) Also Wenlock Shale.

Loc. *Mathon Lodge.*

*Terebratula Wilsoni.* (See Pl. 6. f. 7.) Also Aymestry Limestone.

Loc. *Sitch Wood; Turner Hill.*

*Lingula lata,* Pl. 8. f. 11. Obovate, squarish, flat, smooth; front edge truncated. Width about 2 lines, length 3 lines.

Loc. *Ludlow escarpments, viz., Elton, Evenhay, &c.*

*Lingula? striata*, Pl. 8. f. 12. Obovate squarish, very flat, minutely striated transversely; front edge truncated. Length 5 lines, width 4 lines.

This is of the same shape as the last, but has minute striæ, on its inner surface at least, and thus closely resembles a fish's scale. Is it a shell?

Loc. *Near Aymestry.*

*Euomphalus funatus.* (*M. C.* t. 450.) (See Pl. 12. f. 20.) Also Wenlock Limestone, &c.

Loc. *Myddleton Hall; Abberley.*

*Pleurotomaria undata*, Pl. 8. f. 13. Conical, with a convex base, obtuse; whorls about 4, very convex or round, crossed by many oblique slightly prominent waves; sinus in the lip deep, forming a narrow scarcely elevated band around the whorls; aperture round. Height $2\frac{1}{2}$ inches, diameter $2\frac{1}{4}$ inches.

Loc. *Escarpments near Ludlow; Presteign; Dean's Corner.*

*Pleurotomaria Lloydii*, Pl. 8. f. 14. Conical, with a very convex base, acute; whorls about 5, convex, ornamented with many striæ, 5 carinæ below and 2 above the prominent narrow band which is formed by the filling up of the deep marginal sinus; aperture longer than wide. Height $2\frac{1}{4}$ inches, diameter $1\frac{1}{4}$ inch.

This shell is much longer in form, and has less convex whorls than the last; it is often much pressed; but its carinæ distinguish it well. Named after Dr. Lloyd of Ludlow, whose labours in advancing the objects of this work have been often adverted to.

Loc. *Shelderton Hill; near Aymestry; Dean's Corner.*

*Terebra? sinuosa*, Pl. 8. f. 15. Turreted, subulate; whorls numerous, convex, marked with sharp lines of growth; a wide, shallow, angular sinus in the edge of the lip, the angle a little above the middle. Length $1\frac{1}{4}$ inch, diameter 5 lines.

The sinus in the edge of the aperture is nearly right-angled, but it is indicated in our specimen only by the lines of growth; independent of these lines, the whorls are smooth.

Loc. *Garden House Quarry, Aymestry.*

*Orthoceras Ludense*, Pl. 9. f. 1 *a*. Very gradually tapering, smooth; septa very convex, few; siphuncle central. Diameter 2 inches.

$\beta$. f. 1 *b*. Surface marked with small annular waves near the aperture. Diameter $3\frac{1}{4}$ inches.

This fossil approaches to *O. giganteum* of the Carboniferous Limestone. We provisionally employ a new name until we can define the specific character with greater precision.

The waved lines in var. $\beta$ are probably only lines of growth, and as they are upon the portion free from septa, they may perhaps indicate a full-grown shell; if so, it does not attain to the size of *O. giganteum* of the Carboniferous Series.

Loc. *Ludlow.*

*Orthoceras gregarium*, Pl. 8. f. 16. Very gradually tapering, smooth; septa numerous, distant in the young shell, deep; siphon central, small; aperture round. Length 4 to 6 inches, diameter about $\frac{1}{2}$ an inch.

This shell bears some resemblance to *O. inæquiseptum* of Professor Phillips, but is supposed to be distinct.

Loc. *Ludlow.*

*Orthoceras distans*, Pl. 8. f. 17. Very gradually tapering, smooth; septa almost as distant as they are wide, deep; siphon large, eccentric; aperture nearly round; diameter about $1\frac{1}{4}$ inch.

We have only a few joints in any specimen of this very distinct shell.

Loc. *Near Aymestry; also at the Hay Head Limeworks near Bar Beacon, Staffordshire.*

*Orthoceras eccentricum?* Also Wenlock Shale. (See Pl. 13. f. 16.)

Loc. *Trefnant, Montgomeryshire; in black calcareous nodules.*

*Orthoceras imbricatum*, Pl. 9. f. 2. (*Orthoceratites imbricatus*, "*Wahl.*" *Hising. Petr. Suec.* p. 29. t. ix. f. 9?) Gradually tapering; septa very near, waved.

We have not been able to discover the position of the siphuncle in the shell before us. It resembles *O. undulatum* of M. C. t. 59. in the curvature of the septa, but is more gradually tapering in form, and has not so much tendency to enlarge in the last chamber, and to contract again towards the aperture, which gives the *O. undulatum* a fusiform aspect; it agrees better with *O. imbricatus* of Wahlenberg and Hisinger, which perhaps differs from *O. undulatum* M. C., in the position of the siphon. The *O. undulatus* of Hisinger is *O. annulatum* of M. C., and his *O. annulatus* is probably our *O. Ibex*, for he describes it smooth, in which it differs from *O. annulatum*.

This specimen is much flattened, perhaps by pressure.

Loc. *Ludlow escarpments.*

*Orthoceras filosum*, Pl. 9. f. 3. Rather quickly tapering, longitudinally ribbed; ribs fine, numerous; septa numerous.

This differs from *O. striatum* of M. C. in the coarseness of the lines upon the surface, which in this are sharp elevations. The position of the siphon is unknown; length 1½ foot, greatest width about 4 inches.

Loc. *Ludlow escarpments.*

*Orthoceras virgatum*, Pl. 9. f. 4. Subfusiform, elongated, longitudinally and irregularly but not deeply fluted, grooves 40; septa numerous; length 6 or more inches, diameter one inch and a half.

Nearly like *O. Gesneri* of Martin t. 38; but it has smaller and less regular grooves, and is rather fusiform. *O. angulatus* of Wahlenberg (Hisinger) is curved but is apparently *O. Gesneri* of Martin, and *O. circularis* M. C. is a worn specimen of the same.

Loc. *Mocktree Forest; Abberley Hills.*

*Orthoceras dimidiatum*, Pl. 8. f. 18. Slender; surface transversely undulated, waves reaching only half across; septa moderately distant; length 2½ inches, diameter ¼ inch.

Loc. *Water-break-its-neck, Radnor Forest.*

*Orthoceras fimbriatum.* (See Pl. 13. f. 20.) Also Wenlock shale.

*Orthoceras annulatum*, Pl. 9. f. 5.

This also occurs in the Wenlock shale, and is described hereafter.

*Orthoceras Ibex.* (See Pl. 5. f. 30.) Also Upper Ludlow Rock.

Loc. *Near Ludlow and Western flanks of the Malvern Hills.*

*Orthoceras pyriforme*, Pl. 8. f. 19, 20. Ovato-pyriform, smooth, the chambered portion elongated; septa numerous, even; siphuncle half way between the centre and margin, rather large, inflated between the septa; aperture narrow, enlarged at one extremity where the edge is reflected. Length of inflated portion 4 inches, diameter of ditto 2½ inches.

The last chamber occupies half the ovate portion of the shell, and varies in shape according to the direction of the pressure. The form of the aperture, as far as can be collected from the imperfect specimens in our hands, is curious, being very narrow for about half an inch, and then expanded to circular; the edge is reflected, especially at the larger end of the aperture, where it resembles the beak of a pitcher. This remarkable shell thus forms a link between *Orthoceras* and *Phragmoceras*, differing from the latter only in being straight. Were

it thought necessary to establish a distinct genus, we might perhaps name it *Gomphoceras*, from its club-like form[1].

Loc. *Leintwardine Hill, near Aymestry; also Ledbury in Wenlock Limestone.*

*Cyrtoceras læve*, Pl. 8. f. 21. Also in Upper Ludlow Rock, Pl. 5. f. 34. (For the generic description of Cyrtoceras see Goldfuss.) Elongated, pointed, curved into a semicircle, smooth or only marked with lines, of growth; generally compressed; we have not seen the septa. Length 1½ inch, diameter of aperture 7 lines.

This strongly resembles *Hortolus convolvens* of Steininger, (*Mem. de la Soc. Geol. de France*, vol. i. p. 370. t. xxiii. f. 3.) but has a more even surface.

Loc. *Abberley.*

Phragmoceras (Broderip). (Φράγμα or φραγμὸς, *septum*, κέρας, *cornu.*) Gen. Char. Shell incurved and compressed, more or less conical; septa entire at their edges, crossed externally by the lines of growth; siphuncle near the inner margin; aperture contracted at the middle, its outer extremity produced into a subcylindrical beak.

A genus distinguished from Orthoceras by being curved and having a nearly marginal siphuncle; also from all the species of that genus, except *O. pyriforme*, by the form of the aperture, which further distinguishes it from *Cyrtoceras* of Goldfuss, the aperture of which is round.

*Phragmoceras arcuatum*, Pl. 10. f. 1 *a*. Slightly arched, gibbose, elongated; surface even; siphuncle broad, beak direct? the lines of growth are sharply marked; length 2¾ inches. Length of aperture 1¾ inch.

Around the edge of the last septum is a series of furrows indicating a thickening of the shell about the base of the last chamber; similar furrows, but longer, occur upon the only specimen we have seen of *Orthoceras inflatum* from the Eifel.

Loc. *Ludlow escarpments, and near Ledbury.*

β. Pl. 11. f. 1. Rather more elongated than var. α. Length 2½ inches; length of aperture 1¼ inch.

Loc. *Shelderton Hill, near Ludlow.*

*Phragmoceras ventricosum*, Pl. 10. f. 4, 5, 6. (*Orthoceratites ventricosus? Steininger, Mem. de la Soc. Geol. de France*, vol. i. p. 368. t. xxii. f. 5.) Slightly arched, hooked near the apex, compressed; surface marked with numerous ridges which cross the edges of the numerous septa; aperture nearly closed in the middle, beak produced. Length 6 inches; length of aperture 4 inches.

This is the largest species of the genus; we have not been so fortunate as to detect the siphuncle. F. 4. represents a nearly entire shell; f. 5. is a view of the aperture of a specimen which has been depressed so as to bring the lips nearer in the middle than the natural position; f. 6. is from a specimen which has the beak nearly perfect. If the fossil described by Steininger be the same as our species, the artist has apparently reversed the curve of the septa.

Loc. *Leintwardine Hill, Gardenhouse Quarry, Aymestry; also from the Western flank of the Malverns; Dudley.*

*Phragmoceras compressum*, Pl. 11. f. 2. Much curved, elongated and compressed; marked with distant lines of growth; this is so much curved as to form nearly a circular hook. Longest diameter 3 inches; length of aperture 1¼ inch.

Loc. *Near Aymestry.*

[1] I am indebted to Mr. Proctor, Surgeon, of Leintwardine, for several Orthoceratites, and particularly for one of the most illustrative specimens (f. 20.), which best shows the sudden diminution of the inflated portion towards the apex.

*Phragmoceras? nautileum*, Pl. 10. f. 2, 3. Broad, compressed, much curved; surface transversely waved, waves forked. Length 3 inches; ditto of aperture 2 inches.

We have not seen the septa of this shell; it has much the aspect of a Nautilus, but is too irregular and has no columella.

Loc. *Myddleton Hall. In shale south of the Longmynd.*

*Lituites articulatus*, Pl. 11. f. 5 & 7. Volutions about 3, compressed, crossed by numerous ring-like costæ, whose distance nearly equals their thickness. Diameter of the whorled portion $1\frac{1}{4}$ inch; diameter of aperture 5 lines.

This is suspected to be the involute portion of the same species of shell as that which is called *Orthoceras articulatum*, Pl. 5. f. 31. F. 7. is from a portion a little bent, and approaching the straight specimens, which might have been decidedly referred to this species, but that the involute parts have not yet been found in the same rock with them.

Loc. *Ludlow escarpments; Elton*, f. 5. *Shelderton*, f. 7.

*Lituites? Ibex*, Pl. 11. f. 6. (*Inachus costatus? His. Petr. Suec.*, p. 38. t. xii. f. 2.) This figure represents an arched portion of probably *Orthoceras Ibex*, Pl. 5. f. 30, which therefore approaches to *Lituites*, but we have not seen specimens perfect enough to settle the question.

Loc. *Ludlow; Black Mountain near Clun, Long Mountain near Welch Pool.*

*Lituites giganteus*, Pl. 11. f. 4. Volutions about 3, close, rather compressed, crossed by many oblique arched ribs which are lost over the margin; siphuncle central, aperture nearly square, rounded; the inner whorls slightly indent those around them. Diameter of the last whorl $4\frac{1}{2}$ inches; length of the aperture $1\frac{3}{4}$ inch; width $1\frac{1}{2}$ inch.

Loc. *Mocktree Hays; Churn-bank near Ludlow.*

*Lituites tortuosus*, Pl. 11. f. 3. Irregularly curved; whorls diminishing very slowly; surface even; septa numerous, curved only one way; aperture oblong-ovate, imperfectly 5 angled. Length of aperture $10\frac{1}{2}$ lines, width 8 lines.

We have only an imperfect specimen the chambers of which are filled with black limestone, and the place of the shell with sulphate of barytes, which adheres to the matrix, so that we cannot see the outer surface.

Loc. *Between Welch Pool and Berriw in black calcareous nodules.*

*Bellerophon dilatatus*. (See Pl. 12. f. 23, 24.) Also Wenlock Limestone.

Loc. *Kingsland.*

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## FOSSIL SHELLS OF THE WENLOCK LIMESTONE.

### PLATE XII.

*Leptæna euglypha, Productus euglyphus* passim, f. 1. (*Dalm. Act. Holm.*, 1827. p. 108. t. i. f. 3; *His. Pet. Suec.*, p. 69. t. xx. f. 4.) Sub-prismatic, three-angled, with an obtuse front; flattened above; surface covered with fine radiating, elevated lines and numerous slender ridges; depressed margin large; hinge-area long, narrow, and straight. Length of flat portion 1 inch; width $2\frac{1}{2}$ inches; depth of front 1 inch.

This shell varies in its form, the sides being sometimes less flat than in the figure; the fine lines also are variable, sometimes becoming as large as the slender ridges between which they occur; the sides are extended at the extremities of the hinge-line, and form projecting

angles, which together with the general form serve to distinguish this shell from *Spirifer crenistria* of Phillips, to the flatter valve of which some specimens bear a great resemblance. The striæ are often so like those on *Orthis alternata*, Pl. 19. f. 6., that it is sometimes almost impossible to say to which shell fragments belong.

Loc. *Wenlock; Dudley; Aston, near May Hill; Ledbury; Fownhope; Abberley; and near Wigmore.*

*Leptæna depressa, Productus depressus* passim, f. 2. (*Dalm. l. c.* p. 106. t. i. f. 2; *His. Pet. Suec.* p. 69. t. xx. f. 3; *Productus depressus, M. C.* t. 459.) A shell frequently found on the surface of slabs of limestone at Wenlock and Dudley, and easily distinguished from a somewhat similar fossil which occurs in the Mountain Limestone of the North of England and the Queen's County and other parts of Ireland, and which Prof. Phillips has named *Producta analoga.* In that shell the valves are almost equally convex, and the deflected portion descends very little lower than the convex surface of the lower valve, while in *L. depressa* of our Silurian Rocks, the middle of the lower valve is concave, the sides are expanded like wings at the extremities of the hinges, and the deflected margin is at least as deep as the valve is long. In the *P. analoga,* the outline approaches nearer to a semicircle than in the *L. depressa,* and in this respect agrees better with the *L. rugosa, Dalm.,* a species we believe not yet found in England. Besides its difference in form, *L. depressa* is usually of less size than *P. analoga.* Length of flat portion about $\frac{3}{4}$ inch; width $1\frac{1}{2}$ inch; length of deflected portion nearly 1 inch.

Loc. *Wenlock; Dudley; near Aymestry; Abberley; May Hill; the Lye near Stourbridge. This highly characteristic fossil occurs both in the Aymestry and Wenlock Limestones, but most abundantly in the latter. It is sparingly distributed throughout the other strata of the Silurian Series.*

*Atrypa didyma,* (Dalm.). (See Pl. 6. f. 4.) Also Aymestry Limestone.

Loc. *Limestone Quarries, Eastnor Park, Ledbury.*

*Atrypa tenuistriata,* f. 3. (*Terebratula obtusa, Linn. Trans.,* vol. xii. p. 516. t. 28. f. 3, 4.) Transversely obovate, gibbose, with the beaks rather prominent, and a narrow elevation in the front; longitudinally striated; beaks small, close. Length $1\frac{3}{4}$ inch; width the same.

So nearly is this related to *A. oblata, M. C.* t. 268., which in some states even shows indications of striæ, that it is not easily distinguished, but the position of the beaks affords a strong character. The extent of front which is elevated, varies in different specimens.

Loc. *Wenlock; Croft; Crew's Hill and the Purlieux,* (*Malvern Hills*); *Lindells and Fownhope, Woolhope.*

*Atrypa galeata,* f. 4. & Pl. 8. f. 10. (*Dalm. l. c.* p. 130. t. V. f. 4. *His. Pet. Suec.,* p. 76. t. xxii. f. 1.) Obovate, ventricose, longitudinally furrowed, finely wrinkled with lines of growth; front depressed in the middle; lesser valve convex, the other very deep with a large incurved umbo. Length 14 lines; width the same; depth of each valve $\frac{1}{2}$ inch.

The furrows are chiefly confined to the middle of the shell; they are irregular, and form several teeth in the edge of the deflected portion. The interior has septa resembling those of *Pentamerus*; a section of which is shown in Pl. 8. f. 10.

Loc. *Westhope in Wenlock Edge; near Aymestry, &c.; also Lower Ludlow Rock.*

*Atrypa affinis,* (*M. C.*) (See Pl. 6. f. 5.) Also Aymestry Limestone.

Loc. *May Hill; Limestone Quarries, Eastnor Park; Malvern Hills; Abberley Lodge.*

*Atrypa aspera,* f. 5. (*Dalm. l. c.* p. 128. t. iv. f. 3. *His. Pet. Suec.* p. 75. t. xxi. f. 12. *Ter. asper, Schloth. Nach. Petr.* 1822. p. 68. t. xviii. f. 3.) Orbicular, with the front slightly truncated; marked

with radiating furrows, which increase in number towards the margin, and are crossed by undulating laminæ; valves equally convex. Length ½ inch, width the same.

Distinguished from *A. affinis*, Pl. 6. f. 5. by the equally convex valves, and their more orbicular form.

Loc. *Benthall Edge and other places in the Wenlock Edge.*

*Spirifer radiatus* f. 6. (*M. C.* t. 493.) A very neatly striated shell, which can hardly be confounded with any other. Length 14 lines; width 16 lines; depth of each valve 6 lines.

Although this shell occurs in other situations, it is most abundant in the Wenlock and Dudley Limestone.

Loc. *Wenlock and Dudley; Tynewidd, Caermarthenshire; Abberley Lodge.*

*Spirifer octoplicatus?* f. 7. (*M. C.* t. 562. f. 2, 3.) Our specimen is smaller than those figured in Min. Con., but otherwise agrees with them. The surface is nearly smooth, the plaits 4 on each side of the central one. Length 2½ lines; width 4½ lines. Fragments that appear to be portions of this species, have been met with in several parts of the Silurian System, but not perfect enough to be identified.

Loc. *Abberley; Dudley.*

*Spirifer crispus?* f. 8. (*Delthyris crispa, Dalm. l. c.* p. 122. t. iii. f. 6. *His. Pet. Suec.*, p. 73. t. xxi. f. 5.) Transversely elongated, gibbose, plaited; plaits 5 or 7, crossed by elevated laminæ; beaks remote; extremity of the hinge line obtuse. Length 3½ lines; width 5½ lines, often larger.

In some specimens of this shell, the transverse laminæ are so prominent as to lead us to think they belong to *D. sulcata, Hisinger*, only they do not show the projecting lateral angles which distinguish that species.

Loc. *Dudley; Walsall; Wenlock,* (*very frequent*).

*Orthis rustica*, f. 9. Transversely oblong, rather square, depressed, uneven, with many rounded radii, which become more numerous towards the margin; front straight or slightly elevated. Length 1 inch 1 line; width 1¼ inch.

The hinge area is triangular and rather large; radii between 40 and 50.

Loc. *Wenlock; Valley of Woolhope.*

*Orthis alternata?* (See Pl. 19. f. 6.) Also Caradoc Sandstone.

Loc. *Abberley Lodge.*

*Terebratula lacunosa, Linn.* f. 10. & Pl. 5. f. 19.; also Upper Ludlow Rock. *Schloth. Nach.* 1. p. 68. t. xx. f. 6. *T. borealis, Schl. Von Buch, Tereb.* p. 67. The difficulty in distinguishing between the allied species of plaited *Terebratulæ*, (especially from fragments only) has induced us to figure what may be called similar shells on the Upper Ludlow and Wenlock Limestone plates. It is not impossible, however, that they may be different species, although we cannot, in the specimens we have had to compare, find a distinguishing mark. *T. lacunosa* of Von Buch belongs to the Oolitic Series; and is probably *T. intermedia* of Min. Con. Length 9 lines; width 11 lines.

Loc. *Wenlock Edge; Nash Lime Scar, Presteign; Wallsall.*

*Terebratula crispata*, f. 11. Rhomboidal, convex, transverse, subtrilobate, acutely plaited; plaits about 18, all terminating in the front, about 6 of them raised in the middle; sides smooth; beaks small. Length 10 lines; width 11 lines.

Loc. *Nash Scar, and other places in Radnorshire.*

*Terebratula imbricata*, f. 12. Obovate, transverse, 3-lobed, plaited; plaits twice or thrice forked,

crossed by imbricating scales, especially near the edge; front much elevated. Length 8 lines; width the same.

If specimens we have seen from Sweden be correctly labelled, *T. marginalis of Dalman* is probably the same species.

Loc. *Wenlock Edge.*

*Terebratula cuneata*, f. 13. (*Dalm. l. c.* p. 141. t. vi. f. 3. *His. Pet. Suec.* p. 81. t. xxiii. f. 5.) Triangular, longer than wide, depressed, strongly plaited; plaits 10 or 12, straight, of which a few in the front are elevated; beak of the larger valve straight, produced. Length ½ inch; width 5 lines; depth of each valve 2 lines.

Peculiar to the Wenlock Limestone.

Loc. *Wenlock and Lincoln Hill; Dudley; Abberley.*

*Terebratula bidentata*, f. 13 *a*. (*Dalm. l. c.* p. 142. t. vi. f. 5. *His. Act. Holm.* 1826. t. vii. f. 5. *Pet. Suec.* p. 81. t. xxiii. f. 7.) Triangular, with a rounded front, smooth, depressed, strongly plaited; plaits acute, about 8, two of which in the front are raised; beak sharp. Length 3 lines; width 3½ lines.

Much like the last, but shorter and furnished with fewer plaits.

Loc. *Dudley; Abberley.*

*Terebratula deflexa*, f. 14. Transversely obovate, gibbose, sharply plaited; plaits about 24, of which 4 or 5 in the front are turned downwards; beaks small, adpressed. Length nearly 5 lines; width 6 lines; depth 4½ lines.

A rare species, remarkable for the sinus in the front being in the larger or lower valve.

Loc. *Wenlock Edge.*

*Terebratula Wilsoni*; (See Pl. 6. f. 7.); common at Aymestry; rare in the Wenlock formation.

Loc. *Limestone Quarries, Eastnor Park.*

*Terebratula Nucula?*; (See Pl. 5. f. 20.); also Ludlow Rock.

If this differ at all from the Ludlow species, it is in being rather flatter.

Loc. *Limestone Quarries, Eastnor Park; Dudley; and Western slopes of the Malvern Hills.*

*Patella? implicata*, f. 14 *a*. Oval, depressed, surface composed of concentric laminæ. Longest diameter 2 lines.

We have only seen the upper surface of this small shell, and therefore assign its generic name with doubt; it bears some resemblance to *P. antiquissima*, (*His. Pet. Suec.* p. 45. t. xii. f. 10.) and may represent that fossil in its young state. We have several individuals all of one size, on the same mass of stone with *Spirifer octoplicatus?*.

Loc. *Abberley.*

*Nerita spirata*, var.? f. 15. (*M. C.* t. 463. f. 1, 2.) Subglobose, smooth; spire small; upper part of the whorls flattened; aperture transversely oval. Height ¾ inch; diameter the same.

This has a slightly more prominent spire than *Nerita spirata*, M. C., and the upper part of the whorls are less flattened and smoother; but as the species of the Carboniferous Limestone also varies in these points, we do not feel justified in considering this distinct.

Loc. *Nash Limestone; Presteign; Ledbury; New's Wood, Eastnor Park.*

*Nerita Haliotis*, f. 16. Subglobose, with the last whorl greatly expanded towards the aperture, and irregularly undulated; spire small, rather sunk; aperture orbicular. Height 1 inch; diameter 1 inch 4 lines.

Some specimens are so flat as to resemble a *Haliotis* or *Sigaretus*, and many have a furrow around the upper part of the last whorl.

Loc. *Ledbury, and West flank of Malverns; Wren's Nest, &c., Dudley.*

*Euomphalus discors*, f. 18. (*M. C.* t. 52. f. 1.) The upper part of this shell being covered by coarse undulating laminæ or scales, and the under by fine close ridges only, render it easy to be distinguished.

Loc. *Wenlock; Dudley.*

*Euomphalus rugosus*, f. 19. (*M. C.* t. 52. f. 2. *E. catenulatus. His. Pet. Suec.* p. 37. t. xi. f. 9.) The two surfaces of this shell being alike, distinguish it from the last. We see no reason for supposing *E. catenulatus* of *Hisinger* to be different.

Loc. *Wenlock; Dudley.*

*Euomphalus funatus*, f. 20. (*M. C.* t. 450. f. 1, 2. *His. Pet. Suec.* p. 37. t. xi. f. 11.) The sharp concentric ridges joined by lines of growth, distinguish this species.

Loc. *Wenlock; Dudley; Abberley; Walsall; Benthall Edge; and many other places.*

*Euomphalus sculptus*, f. 17. Depressed, conical; surface ornamented with concentric furrows and elevated lines; whorls about 3; aperture circular; umbilicus large. Height 8 lines; diameter nearly $1\frac{1}{4}$ inch.

The concentric lines and furrows, which are numerous but not deep, give an elegance to this fossil.

Loc. *Ledbury; Eastnor Park.*

*Orthoceras Brightii*, f. 21. Conical, elongated, smooth?; siphuncle nearly central, large, cylindrical; septa $\frac{3}{4}$. Their diameter apart. Diameter about $1\frac{3}{4}$ inch.

Judging from the fragments we have examined of this large specimen, we suppose it to taper more rapidly than its congeners; the marks upon the siphuncle indicate very close septa, but we have not been able to trace the degree of their convexity. The septa have been extended a short way into the siphuncle, which is occupied by stone; the chambers are filled with white calcareous spar, which has received a tinge of brown around the siphuncle. From the rich collection of Mr. B. Bright.

Loc. *Western flanks of Malvern Hills.*

*Orthoceras annulatum.* (See Pl. 9. f. 5.) Also in Wenlock Shale.

Loc. *Hay Head, Walsall; Nash Scar, Presteign.*

*Orthoceras pyriforme.* (See Pl. 8. f. 19 and 20.) Also Lower Ludlow. A small individual; the diameter of the base of its last chamber is nearly $1\frac{1}{2}$ inch.

Loc. *Ledbury.*

*Lituites? Biddulphii*, Pl. 11. f. 8. We have seen a fragment only of this shell, consisting of a cast from the inside of the two last chambers, but it shows that the whorls were flat on their sides, that they increased in size rather rapidly, and that each received a slight impression from the preceding one. The length of the aperture is 17 lines, width 13 lines. Many individuals of the minute shell *Spirorbis tenuis* are imbedded on the cast, having been detached from the inner surface of the *Lituite* where they had taken up their residence after the *Cephalopod* had quitted it. Found by Mr. Ormus Biddulph, whose cabinet has furnished other species for the illustration of this work.

Loc. *Ledbury.*

*Lituites giganteus.* (See Pl. 11. f. 4.) Also Lower Ludlow.

Loc. *Aston near Ludlow.*

*Conularia quadrisulcata, Miller*, f. 22. (*M. C.* t. 260. f. 3 and 4; *His. Pet. Suec.* p. 30. t. x. f. 5; *C. Sowerbii, Defr. Blainv. Malacol.* p. 377. t. xiv. f. 2 *b, c, d* and *e.*) This fossil is little understood. In all probability it ought to be ranked in a higher class than Mollusks. The specimen figured shows a septum in a very perfect condition; it is convex, with a sharpish compressed

umbo in the centre and a deep depression at each of the most remote angles, bearing much resemblance to two siphuncles; its surface is marked with short striæ in the direction of its longest diameter, giving it an aspect totally different from that of the septum in *Orthoceras*. It is one of the few animals of the Silurian period, whose existence would at first sight seem to have been prolonged beyond the æra of the Old Red Sandstone, for forms, approaching very near to our specimens, are found in the ironstone nodules of the carboniferous series. In the Min. Con. no distinction is drawn between the specimens from the transition limestone and those from the carboniferous ironstone. By close comparison, however, it would appear that different species may be established; for the obliquely transverse furrows in the former are crossed by little grooves very regularly arranged over the shell, while in the ironstone specimens the corresponding furrows are either smooth or irregularly grooved; the ridges in both appear when perfect to be crenated, but most distinctly so in the specimens from Coal Brook Dale, from whence Mr. Prestwich has a large collection. If this structure of the surface be sufficient to indicate two distinct species, one must retain the original name, and the other may have that given by Defrance.

By some accident, Hisinger has given to this genus, Lamarck's generic character of *Conilites*, which is probably only the alveolus of a *Belemnite?*. He may possibly have taken the *Conularia teres, M. C.*, for the type of the genus, the square form not having been mentioned in the generic character; but that species it is said, "probably belongs to another genus." Defrance (see De Blainville as above) has referred to both species as different portions of the same. His figures are copied from Mineral Conchology.

Loc. *Wenlock, Dudley, &c.*

*Bellerophon apertus.* (*M. C.* t. 469.) (See Pl. 13. f. 21.) Also Wenlock Shale.

Loc. *Ledbury.*

*Bellerophon dilatatus,* f. 23 and 24. Discoid, smooth; sides largely umbilicated; margin broad, slightly convex, with a central ridge; whorls few; aperture suddenly dilated to a much greater diameter than the spire, and inclosing it, orbicular. Diameter of the spire 1 inch 8 lines, thickness 1 inch, longest diameter of the aperture 3 inches, rather longer than wide.

The last whorl, before it expands to form the large aperture, is twice as wide as long. The edge of the aperture embraces two thirds of the discoid spire; the front of it has no fissure, although there is a ridge upon the whorl which indicates the existence of such a fissure at an earlier period of growth.

Two of our specimens show furrows inside the mouth; the one from the Lower Ludlow Rock is nearly smooth, but has slight indications of them: may not the former be impressions of the outer surface?

Loc. *Burrington near Ludlow.*

*Cornulites serpularius, Schlot.* Pl. 26. f. 5. (*Schloth. Petr.* t. xxix. f. 7.) We can scarcely attempt a description of this anomalous fossil, of which at present but one species is known. So unlike is it to anything we have seen, that we are unable to assign it a place in the system of animals, or draw a comparison between it and any other creature. Its general form is a much elongated, hollow, more or less crooked cone, open at the base; in its early state it is parasitical, being attached by its side and often in pairs. The external crust is longitudinally striated, and marked with slightly raised rings, which indicate its passage over the margins of the series of truncated cones of which the fabric is constructed. These short cones are placed within each other, their widest edges being directed towards the apex of the general envelope, the smallest

or most internal cone occupying the apex itself. Thus they form a pyramid of cups, or if viewed in a reversed position, a series of broad rings gradually increasing in size, and capping but not covering each other. Each cup or ring is thinnest at that part which is inclosed by the succeeding ring, where also its diameter is least; both surfaces are of a foliated structure, and the outer blends with, and is lost in the external coat. Internally, each ring was apparently of a cellular structure, for it is composed of depressed, imbricating, and regularly arranged grains of calcareous spar. Some of the grains leave an impression upon the surface of each of the steps, which is formed upon the cast of the cavity of the cone by the thick edges of the rings. If these cells were the habitations of minute *Polypes,* they must have opened upon the edge of the cup, and each succeeding generation must have been located around the parent stock, and not upon or within the *Polyparium,* as in corals; but there is no appearance of stellæ or radiating laminæ. Upon the cast of the inner cavity may often be observed two, three, or more longitudinal impressions, each composed of two nearly approximating, fine, sunken lines, produced by elevations where probably there were joinings in the cups. The cone of the larger specimens is generally rather straight, with the rings regular, and no appearance of having been attached to any other body; but the young specimens are irregularly curved, have more or less distorted rings, and are fixed upon corals or shells. With such only does Schlotheim appear to have been acquainted, and had not we been supplied with a complete series by Mr. B. Bright, we should have been induced to consider the full-grown specimen as another species of the same curious genus.

Loc. *Western slopes of the Malvern Hills; Dudley.*

TENTACULITES (Schloth.). Gen. Char. Shell subulate, tubular, open at one end; its outer surface surrounded by rings; aperture circular. (*Schloth. Petr.* p. 377.)

Various opinions have been formed concerning the fossils comprised under this generic character, some considering them to be the arms of Crinoidal animals and others the spines of a *Leptæna* (*Recueil des Planches,* 1831. Pl. 6. f. 6, 12 and 13., *Von Buch.*). Their structure is laminated and their shell thin.

*Tentaculites ornatus,* f. 25. (*Tent. annulatus? His. Pet. Suec.* p. 113. t. xxxv. f. 2; *Cyathocrinites pinnatus, in part, Goldfuss, Pet.* vol. i. p. 190. t. lviii. f. 7 *a.*) Subulate, ornamented with large rounded rings at irregular distances, the spaces between them filled with very small rings or striæ; the interior even. Diameter 1 line, length 10 lines. Very frequent on the slabs of limestone.

Loc. *Dudley.*

*Avicula reticulata?* Also Aymestry Limestone, (see Pl. 7. f. 6.)

Loc. *Falfield, Tortworth.*

*Mya?* Three very imperfect specimens.

Loc. *Falfield, Tortworth.*

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## SHELLS OF THE WENLOCK SHALE.

### PLATE XIII.

*Modiola antiqua,* f. 1. Obliquely ovate, rather convex, smooth; anterior lobe indistinct; beaks small, near the anterior extremity. Length 8 lines, width $4\frac{1}{2}$ lines.

This is a shorter shell than *M. Nilssoni* of Hisinger, and does not gape, otherwise it seems to be nearly related to that fossil.

Loc. *Glass House Hill, east flank of May Hill.*

*Leptæna transversalis,* f. 2. (*Dalm. l. c.* p. 109. t. 1. f. 4; *His. Pet. Suec.* p. 69. t. xx. f. 5.) Semicircular, very convex, finely striated and costated longitudinally; costæ linear, distant; hinge inflected; hinge line straight, equal in length to the width of the shell; lesser valve very concave. Length about 7 lines, width 8 or more.

Loc. *Hay Head and Tame Bridge, near Wallsall; Woolhope; Burrington; Buildwas Bridge; Stumps Wood, near Ledbury.*

*Leptæna lævigata,* f. 3. Semicircular, depressed, with projecting angles or ears at the extremities of the hinge line; surface shining, obscurely marked with minute concentric waves and a few radiating lines; front slightly depressed. Length $2\frac{1}{2}$ lines, width excluding the ears 4 lines.

It may be doubted whether this be an *Orthis* or *Leptæna*; we have seen but one valve.

Loc. *Burrington, near Ludlow.*

*Leptæna minima,* f. 4. Hemispherical, sharply radiated; radii alternately long and short, smooth. Length 2 lines, width 3 lines.

A very neatly formed and regularly striated species.

Loc. *Burrington.*

*Leptæna euglypha.* (See Pl. 12. f. 1.) Also Wenlock Limestone.

Loc. *Woolhope.*

*Leptæna depressa.* (See Pl. 12. f. 2.) Also Wenlock Limestone.

Loc. *Woolhope; Tynewidd; Croft; Hay Head; Frith Wood Coppice.*

*Atrypa compressa,* f. 5. Ovato-orbicular, transverse, rather compressed, smooth; front slightly indented; beaks very small. Length 5 lines, width 6 lines.

Loc. *Woodside and Nash, near Presteign.*

*Atrypa depressa,* f. 6. Transversely obovate, compressed, smooth, with about 3 obscure furrows along the middle; sides depressed; the front much elevated; the elevated portion square; beaks unequal. Length 4 lines, width 5 lines.

Loc. *Stumps Wood, Malverns; Delves Green, near Wallsall.*

*Atrypa rotunda,* f. 7. Nearly orbicular, very convex, smooth, with 5 obscure furrows; front elevated; beaks small, equal. Length 7 lines, width $7\frac{1}{2}$ lines.

Loc. *Escarpments of Wenlock Edge.*

*Atrypa linguifera,* f. 8. Orbicular, very convex, smooth; front elevated, the elevated portion tongue-shaped; beaks large, unequal. Length 9 lines, width the same; depth of both valves together $7\frac{1}{2}$ lines.

A nearly globose shell with prominent beaks.

Loc. *Stumps Wood; Valley of Woolhope; Delves Green.*

*Atrypa tenuistriata.* (*Terebratula obtusa, Sowerby in Linn. Trans.* vol. xii. p. 516. t. 28. f. 3 and 4.) (See Pl. 12. f. 3.) Also Wenlock Limestone.

Loc. *Woolhope; Malvern Hills.*

*Atrypa galeata.* (See Pl. 12. f. 4.) Also Wenlock Limestone.

Loc. *Delves Green and Hay Head, near Wallsall; Frith Wood, near Ledbury; Woolhope.*

*Atrypa affinis.* Also Aymestry Limestone. (See Pl. 6. f. 5.)

Loc. *Stumps Wood; Tame Bridge; Nash; Hay Head; Croft; Woolhope; Frith Wood Coppice; Delves Green.*

*Atrypa aspera.* (See Pl. 12. f. 5.) Also Wenlock Limestone.
Loc. *Delves Green; Hay Head; Woolhope; Stumps Wood.*

*Spirifer? Pisum,* f. 9. Lenticular, convex, indistinctly six-sided, smooth; front even, truncated; beaks equal, small; the area between them triangular, small. Length 3 lines, width the same.
Loc. *Hay Head.*

*Spirifer trapezoidalis.* (See Pl. 5. f. 14.) Also Ludlow Rock.
Loc. *Stumps Wood, and other places west side of Malvern Hills.*

*Spirifer radiatus.* (See Pl. 12. f. 6.) Also Wenlock Limestone.
Loc. *Woolhope; Hay Head and Tame Bridge, Wallsall.*

*Spirifer crispus.* (See Pl. 12. f. 8.) Also Wenlock Limestone.
Loc. *Wallsall.*

*Spirifer sinuatus,* f. 10. (*Terebratula sinuata, Sowerby in Linn. Trans.* vol. xii. p. 516. t. 28. f. 5 and 6; *Delthyris cardiospermiformis; His. Anteckn.* vol. iv. t. 7. f. 6; *Dalm. l. c.* p. 124. t. 3. f. 7; *His. Pet. Suec.* p. 74. t. 21. f. 9; *Sp. cardiospermiformis; Von Buch sur les Spirifers et Orthis,* t. 1. f. 7.) Obcordate, deeply two-lobed, eared, longitudinally striated; larger valve very deep, with an incurved beak; area between the beaks triangular. Length 3½ lines, width about the same, often more.

A drawing and description of this curious shell was sent to the Linnean Society in 1815, under the name *Ter. sinuata,* and printed in 1818, it is therefore necessary to retain that specific name. The length of the hinge line is liable to much variation; in some cases it equals the width of the shell.
Loc. *Malvern; Hay Head.*

*Orthis hybrida,* f. 11. Lenticular, most convex near the beaks, wider than long, radiated; radii increasing in number towards the margin; front rather straight; valves equal; hinge line short. Length 5½ lines, width 6 lines.

In the short hinge line this species forms a link with the genus *Atrypa*; but the narrow area between the beaks and striated surface distinguished it as an *Orthis.*
Loc. *Hay Head, Wallsall.*

*Orthis filosa,* f. 12. Semioval, very flat, finely radiated; radii very numerous, unequal; hinge line equal to or exceeding the length of the shell; sides rather straight; beaks scarcely elevated. Length 10 lines.

This is a delicate thin shell; the radii resemble threads, stretched from the beaks to the margin.
Loc. *Burrington; and also at Oldcastle, Malvern.*

*Orthis canalis,* f. 12 *a.* (See Pl. 20. f. 8.) Also in Caradoc Sandstone. Semioval, finely radiated; radii more numerous near the margin; larger valve very deep, with a pointed incurved beak; the other concave along the middle, slightly convex along the sides; front rather pointed and gently depressed; hinge line shorter than the width of the shell. Length 6½ lines, width about the same.

This form resembles *Orthis elegantula* of *Dalman,* but as it cannot be positively identified we venture to give it a new name; it is an extremely neat shell, with a hinge line shorter than any of Dalman's figures.
Loc. *Delves Green; Croft; Tame Bridge; Woolhope (Falfield, near Tortworth).*

*Orthis antiquata,* f. 13. Semicircular, depressed, radiated; radii deeply divided by distant lines of growth; principal radii few, with shorter intermediate ones near the margin; lesser valve flat; dorsal area narrow, the full width of the shell. Length 6 lines, width about 8 lines.

Loc. *Woolhope.*

*Terebratula læviuscula,* f. 14. Rhomboidal, slightly convex, smooth; front rounded, even; sides angular. Length 3 lines, width the same.

Loc. *Tynewidd, Llandovery.*

*Terebratula brevirostris,* f. 15. Transversely elliptical, plaited; plaits about 25, sharp; margin even; valves very convex, nearly equal; beaks large, short. Length 4 lines, width 6 lines.

Loc. *Croft Valley; Woolhope.*

*Terebratula interplicata,* f. 23. Obovate, transverse, plaited; plaits sharp, principal ones about 14, the four middle ones depressed at the front, and between each lateral one is a shorter plait; valves very convex, nearly equal; beaks short, nearly equal; the sides near the beak smooth, with prominent edges. Length 5 lines, width $5\frac{1}{2}$ lines, depth 3 lines.

Loc. *Woolhope; Delves Green.*

*Terebratula sphærica,* f. 17. Orbicular, ventricose, plaited all over; plaits about 14, many of them forked, rather obtuse, 3 or 4 middle ones much depressed at the front, forming a longitudinal canal; beaks equal, short; sides concave. Length, width and depth about 6 lines.

Loc. *Tame Bridge.*

*Terebratula crebricosta,* f. 18. Obovate, transverse, subcylindrical, depressed, plaited; plaits about 30, rather sharp, 6 or 8 of them raised into a deep sinus in the edge of the upper valve; beaks small, acute. Length 7 lines, width 8 lines.

Loc. *Tynewidd, Llandovery.*

*Terebratula Stricklandii,* f. 19. Obovate, transverse, ventricose, plaited; plaits about 30, sharp, 5 of them raised at the front, producing a broad elevation in the upper and more convex valve, and a corresponding canal in the other flatter one; beaks small, sharp, adpressed; near that in the upper valve is a longitudinal canal; sides smooth near the beaks. Length 11 lines, width 13 lines.

Communicated by Mr. H. E. Strickland, after whom it is named.

Loc. *Longhope.*

*Terebratula imbricata, var.* f. 27. (See Pl. 12. f. 12.) Also Wenlock Limestone. This is a shorter variety than that figured in Pl. 12., and many specimens are much more ventricose, though smaller.

Loc. *Woolhope; Stumps Wood; Hay Head; Tame Bridge; Croft.*

*Lingula Lewisii?* (See Pl. 6. f. 9.) Also Aymestry Limestone.

Loc. *Buildwas; Wenlock; Tynewydd.*

*Euomphalus alatus* (*Wahlenberg*), f. 28. (*His. Pet. Suec.* p. 36. t. xi. f. 7.) Conical, depressed, marked with prominent lines of growth; umbilicus very open; margin winged, entire. Height $\frac{1}{2}$ an inch, diameter 1 inch 4 lines.

Loc. *Delves Green; Tame Bridge.*

*Euomphalus funatus.* (See Pl. 12. f. 20.) Also Wenlock Limestone.

Loc. *Woolhope.*

*Turbo cirrhosus,* f. 22. Conical, turreted, whorls few, round, longitudinally grooved; grooves about 6, broad; aperture round; umbilicus open. Length $2\frac{1}{4}$ inches, diameter of the base $1\frac{3}{8}$ inch.

Loc. *Wenlock.*

*Orthoceras eccentricum,* f. 16. Also Lower Ludlow Rock. Very slightly tapering, obscurely striated and furrowed longitudinally; septa very numerous, almost flat; siphuncle eccentric. Diameter $1\frac{1}{4}$ inch.

Loc. *Old Radnor.*

*Orthoceras Nummularius*, f. 24. Conical?, smooth?; septa very numerous, very convex, $\frac{1}{9}$th their diameter apart; siphuncle large, inflated between the septa to about 3 times its own diameter, and $\frac{1}{3}$ the diameter of the septum. Diameter about 4 inches.

This much resembles *O. crassiventris, Wahl.* (*His. Pet. Suec.* p. 30. t. x. f. 3.) but in that species the siphuncle fills $\frac{2}{3}$rds of the diameter of the chamber, and the septa are not so close. Portions of the siphuncle when separated, resemble thick, coarsely made coins.

Loc. *Whitfield Quarry, Tortworth.*

*Orthoceras attenuatum*, f. 25. This figure is taken from a drawing supplied by Dr. Lloyd from a fine specimen discovered by him, and now in the Ludlow Museum.

Loc. *Banks of the Onny, near Stretford Bridge.*

*Orthoceras virgatum.* (See Pl. 9. f. 4.) Also Lower Ludlow Rock.

Loc. *Stumps Wood.*

*Orthoceras canaliculatum*, f. 26. Very gradually tapering, longitudinally furrowed; furrows about 26, shallow, regular; siphuncle central, small. Diameter $1\frac{1}{4}$ inch.

Somewhat resembling *O. Gesneri, Martin,* but much less conical and the septa more numerous than in that species. It differs from *O. angulatus, Wahl.* (*His. Pet. Suec.* p. 28. t. x. f. 1.), in having a central siphuncle, and in being straight.

Loc. *Ledbury.*

*Orthoceras fimbriatum*, f. 20. Gradually tapering, straight and even; ornamented with transverse many arched laminæ or flounces, about one line apart, and slight irregular longitudinal furrows and striæ; siphuncle central, large; septa moderately numerous. The arches of the laminæ terminate in the furrows. Diameter 2 or more inches.

This differs from the following in the position of the arches of the laminæ and in the generally even surface. A specimen in Mr. B. Bright's cabinet contains 3 smaller *Orthocerata.*

Loc. *Aston, May Hill; also on the western slopes of the Malverns.*

*Orthoceras annulatum.* Pl. 9. f. 5. (*M. C.* 133; *O. undulatus, Hisinger Anteckn.* p. 236. t. vii. f. 8; *Pet. Suec.* p. 28. t. x. f. 2. It is not *O. nodulosus* of Schlotheim which has been referred to *O. annulatum* of *M. C.*) Very gently tapering, ornamented with prominent transverse rings, very numerous, transverse, many-arched laminæ, and more or less deep longitudinal furrows; siphuncle central, large; septa equal in number to the rings; the arches of the laminæ terminate between the furrows. Diameter $1\frac{1}{2}$ inch.

The longitudinal furrows in this species are sometimes hardly perceptible, but whenever they can be perceived, the arches of the flounces will be found to spring from the raised spaces between them.

The figure in *Min. Con.* was taken from a fossil in which the furrows were very slight; our figure is from the more deeply furrowed variety. We have also a specimen in which the fimbriæ are nearly as distant as in the last species, although usually there are four times as many. One individual in Mr. B. Bright's cabinet contains two other small *Orthocerata* penetrating the chambers; one of them is annulated and has a lateral siphuncle[1].

[1] The *Orthoceras annulatum* of the Silurian Rocks is very prevalent in strata of the same age on the continent, where it is known as *O. undulatum.* This confusion is the more to be regretted, as Mr. Sowerby had previously figured another species from the "Carboniferous Limestone" under the latter name. My readers who may refer to the original figure of *O. annulatum* in the Mineral Conchology, will, however, be surprised to see that it differs considerably from the fossil given in this work; but Mr. J. Sowerby contends that his species is identical with those I have collected, and hence I have retained the name first applied to the fossil.—R. I. M.

Loc. *Stumps Wood, near Malvern; Tynewidd.*

*Bellerophon Wenlockensis*, f. 21. (*M. C.* t. 460.) This specimen differs a little from the species of the Carboniferous Limestone figured in *M. C.*, but it is difficult to indicate a real difference owing to the calcareous spar having taken the place of the shell. We assign it provisionally the name of *B. Wenlockensis.*

Loc. *Wenlock; Croft, Malvern.*

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Several of the shells, figured as belonging to the Wenlock shale, may be classed either with the Wenlock or Caradoc formation. They, in truth, belong to the beds of passage between the Upper and Lower Silurian Rocks, and are therefore common to both. (Ex. Tynewidd, near Llandovery, &c.)

# CHAPTER XLVI.

## SHELLS OF THE LOWER SILURIAN ROCKS.

*Shells of the Caradoc Formation,* Pls. 19, 20 and 21.—*Shells of the Llandeilo Flags,* Pl. 22.

LET us now see to what extent the *mollusca* of the Lower Silurian are distinguishable from those of the Upper Silurian Rocks. In the first place we may repeat, that although a very few species of shells are found nearly throughout the Silurian System[1], by much the greater number which we are about to examine, are dissimilar from those described in the preceding chapter. Secondly, it may be said, that this inquiry has led to the development of an important modification of the distribution of species during those ancient periods;—namely, that in these, the lowest rocks of which the fossils have been closely scrutinized, the same species is ascertained to pervade a much greater thickness of strata than in the overlying deposits. For, not only are many of the mollusks of the Caradoc Sandstone common to the Llandeilo Flags, but some of them are also detected in strata of the Cambrian System, far, indeed, beneath the upper limit of that system, as at present assumed. Hence we are entitled to assert, that such shells must have lived through much longer epochs than any species in the younger accumulations; and further, looking to the smaller number of species which we can detect in the older rocks, we may believe, that new forms were less frequently called into existence than in succeeding ages.

If, however, it be granted that a good many species of mollusks are common to vast accumulations, embracing the Lower Silurian and Upper Cambrian groups, we are still not at liberty to infer that there is no zoological demarcation between the two systems, and therefore that the Silurian System is without a base. We have already shown, that throughout the overlying geological series, no two great contiguous systems are ever abruptly separated from each other, except in those tracts where the order of deposit has been broken up.

Thus, passing over more modern analogies, we know that wherever the lower beds

[1] Three or four species of shells range from the Ludlow to the Caradoc formation inclusive, though each species is much more common in *one* formation than in any other.

I may, however, here state that Trilobites (crustaceans) more precisely mark the age of each deposit in which they occur than mollusks. (See the ensuing chapter.)

of the Old Red Sandstone graduate into the Upper Silurian Rocks, there the conterminous deposits contain many similar fossils; and the same is observed when we descend from the Silurian amid the Cambrian Rocks. We must, however, admit that this lower transition zone is of vastly greater dimensions than in any of the younger formations, and that we are not yet acquainted with its lower limit.

The examination of all the fossils of the Cambrian System will eventually determine this point, by showing us what new forms appear as we pass through that great slaty series and approach the lowest strata in which the vestiges of life have hitherto been detected. This interesting subject will be cleared up by the labours of Professor Sedgwick.

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## FOSSIL SHELLS OF THE CARADOC SANDSTONE AND LLANDEILO FLAGS OR LOWER SILURIAN ROCKS.

PLATES XIX, XX, XXI AND XXII.

*Arca Eastnori*, Pl. 20. f. 1. Transversely ovate, smooth?, very convex; beaks central, short; shell thick; muscular impressions deep, especially the posterior one; hinge teeth numerous, slightly diverging. Length 8 lines, width 14 lines; one imperfect specimen from Golden Grove is nearly $1\frac{3}{4}$ inch wide.

In the specimens from Eastnor Park, f. 1 *a*., the casts of the inside show a deep channel bordering the rising corresponding to the posterior muscular impression. In those found at Golden Grove a similar channel, though not so deep, also accompanies the anterior muscular impression f. 1 *b*. If the latter be not an old shell grown very thick, it may be a different species; it somewhat resembles the imperfect *Arca* mentioned in the description of the shells from the Old Red Sandstone.

Loc. *In Caradoc Sandstone, near the obelisk of Lord Somers in Eastnor Park; also near Golden Grove, Llandeilo.*

*Nucula? lævis*, Pl. 22. f. 1. Oval, transversely elongated, ventricose, smooth. Length $3\frac{1}{2}$ lines, width nearly 2 lines.

Loc. *Pensarn, near Caermarthen, in black schist.*

*Avicula orbicularis*, Pl. 20. f. 2 and 3. (*Pleurobranchus? G. B. Sowerby in Geol. Trans.* p. 268 and 340. t. xxxiii. f. 2.) Orbicular, becoming oblong by age, convex, nearly smooth; beaks prominent; ears small, the anterior one round. Length of the rounder variety $1\frac{1}{2}$ inch, width the same.

Fig. 3. is the form of the old shell or elongated variety from Acton Scott. In some specimens the lines of growth form obtuse ridges. Length 2 inches 2 lines, width 1 inch 8 lines.

Loc. *Horderley; Cheney Longville; and Acton Scott, near the Caradoc; also near Ems, Nassau?*

*Avicula obliqua*, Pl. 20. f. 4. Obliquely ovate, elongated, convex, smooth; hinge line rather short; ears undefined. Length $1\frac{3}{4}$ inch, width nearly as much.

This species occurs in clusters in the Caradoc Sandstone.

Loc. *Soudley, near Acton Scott, east flank of Caer Caradoc.*

*Orbicula granulata,* Pl. 20. f. 5. Lenticular, punctated.

This is an imperfect specimen, but from its remains we presume that it was very flat, with the apex near the margin. Diameter about ½ an inch.

Loc. *Chatwall, east flank of the Caradoc.*

*Leptæna sericea,* Pl. 19. f. 1. (*L. striatella? Dalm. l. c.* p. 111. t. i. f. 5.) Semicircular; finely striated longitudinally, with a silky lustre; a few striæ deeper than the others; larger valve convex, the other nearly flat; front not concave, considerably deflected at the edge. Length 5 lines, width 10 lines.

In general form this fossil resembles *L. lata* of the Ludlow Rock (Pl. 5. f. 13.), but has much finer striæ and more angular sides; the front also is straighter, and there are no indications of spines. Sometimes a few concentric lines of growth are conspicuous.

Loc. *Whittingslow; Horderley, and east flank of Caradoc*[1]*; Guilsfield and Cefn, near Welchpool; the Maen and Allt-yr-ankr, Meifod; east flank of Berwyns; Goleugoed; and Cerrig-gwynion, Llandovery.*

*Leptæna sericea,* var., Pl. 19. f. 2. Rather longer than the last.

Loc. *Cefn-rhyddan, Llandovery.*

*Leptæna complanata,* Pl. 20. f. 6. Semioval, nearly as long as wide, almost flat, finely radiated; radii linear, increasing in number towards the deflected margin; beak projecting; the extremities of the hinge line rounded. Length 11 lines, width 1 inch, one imperfect specimen is larger.

Loc. *Acton Burnell, Salop.*

*Leptæna duplicata,* Pl. 22. f. 2. Transverse, convex, internally marked with furrows arranged in pairs. Length 5½ lines, width 9 lines.

Loc. *Cefn, near Welchpool; Robeston Wathen, Pembrokeshire.*

*Leptæna euglypha,* Pl. 12. f. 1. Wenlock Limestone.

Loc. *Horderley; and Cefn, near Welchpool.*

*Leptæna depressa,* Pl. 12. f. 2. Occurs from the Aymestry Limestone downwards through the inferior strata.

Loc. *Hope Mill, Shelve; Goleugoed, Mandinam, Caermarthenshire.*

*Leptæna tenuistriata,* Pl. 22. f. 2 *a.* Semicylindrical, closely striated; top of the upper valve with 12 or more concentric rugæ, convex; sides expanded.

A shell much resembling *L. depressa,* and about the same size, but ornamented with much closer striæ and of a thinner substance. Can this be *L. depressa* of Swedish authors, and may our *L. depressa* be their *L. rugosa*?

Loc. *Marloes Bay; Narbeth, Pembrokeshire; also at Gaerfawr in the Caradoc Sandstone of Montgomeryshire.*

*Atrypa crassa,* Pl. 21. f. 1. Spherical, smooth? very thick, the three muscular impressions very deep, the central one tongue-shaped, striated, the lateral ones marked with 5—7 angular furrows more or less deep.

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[1] Whenever the reference "east flank of Caradoc" is given, the fossils alluded to, may be detected at Soudley Quarries near Hope Bowdler, Wilson, Enchmarsh, Broome, Chatwall, and in the hills ranging to Acton Burnell and Stevens Hill on the north-east, and to Acton Scott, Whittingslow, Horderley, Long-Lane, Wistanstow, Cheney Longville, Aston and Corton on the south-west.

We have only seen casts of portions near the beak of this shell, but there is enough to show that it must have been very heavy. F. 1*b*. probably indicates a variety with irregular cells rather than furrows. Diameter about $1\frac{3}{4}$ inch.

This and the following figure belong to the lowest beds of the Silurian System.

Loc. *Cefn Rhyddan; Caermarthenshire.*

*Atrypa undata*, Pl. 21. f. 2. Transversely elliptical, gibbose, smooth; an elevation along the middle leads to a tongue-shaped sinus in the edge of one valve, and a corresponding projection in the other. Length 10 lines, width 1 inch 4 lines.

Loc. *Cefn Rhyddan, Llandovery; west side of Cefn-y-Garreg, Llandovery; Robeston Wathen, Pembrokeshire.*

*Atrypa Lens*, Pl. 21. f. 3. Suborbicular, depressed, smooth, obscurely radiated, elevated along the middle of the upper valve. Length nearly $2\frac{3}{4}$ inches, width about 2 inches.

Loc. *North end of Snead's Heath* (*Lickey Quartz*); *Mandinam and Cefn Rhyddan, Llandovery.*

*Atrypa plana*, Pl. 21. f. 4. Orbicular, with the front rather produced, flattened, smooth. Length about 7 lines, width 8 lines.

Loc. *Tynewidd, Llandovery.*

*Atrypa globosa*, Pl. 22. f. 2 *b*. Globose, obscurely channelled, smooth. Diameter about 6 lines.

Loc. *Castell Craig, Gwyddon; and Gorllwyn-fach, Caermarthenshire.*

*Atrypa polygramma*, Pl. 21. f. 4 *a*. Transversely obovate, finely radiated, valves unequally convex, the lower with a wide, shallow canal along the middle; radii increasing in number towards the margin. Length 1 inch, width 1 inch.

Loc. *Powis Castle.*

*Atrypa orbicularis*, Pl. 19. f. 3 and 4. Suborbicular, rather wider than long, with a slight sinus in the front, furrowed; furrows numerous, forked, the ridges between them not scaly; valves equal. Length 7 lines, width 8 lines.

Much resembling *A. aspera*, but smoother.

Loc. *Gorllwyn-fach* (f. 1.); *Conygree Coppice* (f. 4.); *Woodford Hill, Abberley; Malvern Ridge, End Hill.*

*Atrypa hemisphærica*, Pl. 20. f. 7. Almost orbicular with the back nearly straight, radiated; radii about 12, angular; valves unequal, one hemispherical, the other nearly flat. Length 4 lines, 5 lines.

A beautiful fan-like shell.

Loc. *Ankerdine Hill, Worcestershire; Damory Hill, Michaelwood Chace, Gloucestershire.*

*Atrypa affinis*, Pl. 6. f. 5. Ranges from the Aymestry Limestone to the upper beds of the Caradoc Sandstone.

Loc. *Cefn, Welch Pool to the Breiddens; Tynewidd; Golden Grove; Marloes Bay, Pembrokeshire; Lower Lickey* (*overlying beds*).

*Atrypæ*, Pl. 22. figs. 3, 4 and 5. These are curious casts of different valves, but so much distorted that we cannot determine their general form, nor even say whether or not they belong to the same species. Figs. 4 and 5 are two views of one specimen.

Loc. *Marloes Bay, Pembrokeshire.*

*Spirifer radiatus*, Pl. 12. f. 6. Ranges from the Wenlock Limestone to the upper beds of the Caradoc formation.

Loc. *Gaerfawr, Guilsfield; Lower Lickey* (*overlying beds*).

*Spirifer radiatus*, var., Pl. 21. f. 5. The beak of this variety is not curved as in the ordinary form of *S. radiatus*.

Loc. *Castell craig-gwyddon, Llandovery.*

*Spirifer plicatus*, Pl. 21. f. 6. Semicircular, convex, sharply plaited, especially towards the margin; beaks near each other, hinge line nearly double the length of the shell. Length 11 lines, width 1 inch 7 lines.

Loc. *Goleugoed, Llandovery; Bala?*

*Spirifer alatus*, Pl. 22. f. 7. Semicircular with expanded cuspidate sides, plaited, slightly raised in the middle; plaits about 18, acute. Length $5\frac{1}{2}$ lines, width $9\frac{1}{2}$ lines.

Loc. *Pensarn and Mount Pleasant, Caermarthen.*

*Spirifer liratus*, Pl. 22. f. 6. This represents the distorted cast of a large *Spirifer* or *Orthis*. Length nearly 3 inches.

Loc. *Marloes Bay, Pembrokeshire.*

*Spirifer? lævis*, Pl. 21. f. 12. Semicircular, compressed, smooth; a slight elevation along the middle; beaks rather prominent, the area between them narrow with parallel edges. Length 8 lines, width twice as much.

In general form this shell approaches to that of *Orthis*.

Loc. *May Hill, Gloucestershire; Noeth-grüg, Llandovery; Gullet Wood, Eastnor Park; Hope Mill, Salop; Lower Lickey* (*overlying beds*).

*Orthis grandis*, Pl. 20. f. 12 and 13. Semi-oval, short, nearly flat, irregularly radiated within; radii numerous, forked. Length about $1\frac{1}{2}$ inch, width nearly 2 inches.

Having only seen impressions of the interior of this fine shell; the description, as in many similar cases, is necessarily incomplete.

Loc. *Horderley; Acton Scott; and flank of Caradoc.*

*Orthis expansa*, Pl. 20. f. 14. Semicircular, flat, internally plaited near the margin; muscular impression deeply furrowed. Length 1 inch 7 lines, width 2 inches.

Loc. *Moel-y-Garth and Gaerfawr, near Guilsfield.*

*Orthis alternata*, Pl. 19. f. 6. Transversely obovate, finely radiated; one valve convex, the other flat or concave; radii extremely numerous, of unequal fineness and increasing in number towards the edge; hinge line shorter than the width of the shell. Length 10 lines, width 13 lines.

Loc. *Whittingslow; Soudley; and east flank of the Caradoc; Alt-yr-ankr; and the Maen Meifod; Lower Lickey Ridge; east flank of Berwyns; Mandinam, Llandovery.*

*Orthis compressa*, Pl. 22. f. 12. Lenticular, compressed, with a straight hinge line; striato-punctated throughout its substance. Length 1 inch; width 14 lines.

Loc. *Hope Quarry, near Shelve, Salop.*

*Orthis protensa*, Pl. 22. f. 8 and 9. Semioval, depressed, radiated; radii linear, sharp, unequal in thickness. Length 8 lines, width 7 lines.

Loc. *Goleugoed; Meadow Town, near Shelve; Berwyns.*

*Orthis anomala*, Pl. 21. f. 10. (*Anomites anomalus, Schl. Nacht. Pet.* 1. p. 65. t. xiv. f. 2.) Oblong with straight sides, convex, striated. Length 1 inch 7 lines, width 1 inch 5 lines.

Only one valve has fallen under our observation, we are not sure therefore that the margin would be like that in Schlotheim's figure.

Loc. *Horderley; east flank of Caradoc; east flank of Berwyns.*

*Orthis Pecten?*, Pl. 21. f. 9. (*Dalm. l. c.* p. 110. t. i. f. 6; *His. Pet. Suec.* p. 70. t. xx. f. 6.) Semi-oval, short, convex, finely radiated; radii nearly equal, cut by the lines of growth; hinge

line equal to the width of the shell; one valve nearly flat. Length $1\frac{1}{2}$ inch, width 1 inch 11 lines.

Having seen specimens of several distinct species sent from Sweden, as *O. Pecten*, it is with some doubt we refer our shell to that name.

Loc. *Horderley, Caradoc and Meadow Town, Salop; the Maen, near Meifod.*

*Orthis semicircularis*, Pl. 21. f. 7. Semicircular, slightly produced in front, convex, radiated; radii 30, sharp, increasing in number towards the margin; beak projecting. Length $3\frac{1}{2}$ lines, width $\frac{1}{2}$ an inch. (It occurs in the Silurian Rocks of North Devon, near Barnstaple.)

Loc. *South of Bogmine, at Hope, in the Corndon or Shelve Hills.*

*Orthis Flabellulum* (α), Pl. 21. f. 8. Transversely obovate, with about 24 large, rounded, smooth radii; hinge line less than the width of the shell, slightly arched; one valve flat, the other convex with a slight channel in the middle. Length $8\frac{1}{2}$ lines, width 13 lines.

In this shell the ribs are remarkably regular, their breadth equal to the spaces between them, and they continue strongly marked to the very beak; the outline is very regularly rounded and forms an obtuse oval. Can this be *O. callactis* α of Dalman? (*L. c.* p. 112. t. ii. f. 2.) It appears to have a wide range, descending deep into the Cambrian System.

Loc. *Corton, Clunbury and other places in true Caradoc Sandstone; Bala and Snowdon in Cambrian Rocks.*

*Orthis Flabellulum* (β), Pl. 19. f. 8. This variety is rounder than α and has a few short radii between the long ones. Length 11 lines, width 14 lines.

Loc. *East flank of the Caradoc.*

*Orthis virgata*, Pl. 20. f. 15. The specimens of this species are very imperfect; it resembles the last, but has above 30 in place of 24 radii. Length $8\frac{1}{2}$ lines, width 11 lines.

Loc. *Acton Scott; Horderley; Llanwyth, Builth.*

*Orthis radians*, Pl. 22. f. 11. Semicylindrical, concave in front, compressed, plaited; beaks elevated; plaits about 15, sharp. Length $4\frac{1}{2}$ lines; width $\frac{1}{2}$ an inch.

Loc. *Goleugoed; Llandegley.*

*Orthis? costata*, Pl. 21. f. 11. Semicircular, with angular sides and about 20 unequal sharp radii. One valve somewhat conical, with a large triangular area beneath the beak. Length $5\frac{1}{2}$ lines, width $7\frac{1}{2}$ lines.

Only one imperfect valve has come to our knowledge.

Loc. *Cefn, near Welch Pool.*

*Orthis Actoniæ*, Pl. 20. f. 16. Transversely obovate, with about 14 large radii, trifid or quadrifid at their extremities; one valve flat, the other very convex. Length $8\frac{1}{2}$ lines, width 11 lines.

Greatly resembling *O. Flabellulum*, but known at once by the forked radii, a character particularly useful in distinguishing the species among the slaty rocks.

Named after Mrs. Stackhouse Acton, in whose property, near Church Stretton, it is abundant.

Loc. *Acton Scott, Horderley, and the flanks of the Caradoc; also in the Llandeilo Flags, and in the Cambrian Rocks of Bala.*

*Orthis callactis*, β? Pl. 19. f. 5. (*Dalm. l. c.* p. 113.) Almost circular, but wider than long, nearly flat, ornamented with about 20 rounded radii, which are obscure towards the beaks. Length 7 lines; width 9 lines.

The most convex valve of this, is much flatter than the convex valve of *O. Flabellulum*, which otherwise it much resembles.

Loc. *Old Storridge Hill, Worcestershire; Caradoc Hills; Hope Mill, Salop.*

*Orthis lata*, Pl. 22. f. 10. Semicylindrical, rather straight in front, depressed, radiated; radii linear, unequal in thickness. Length 5 lines; width 9 lines.

This much resembles *Leptæna lata*, but both valves are convex, the radii unequal in size, and there are no spines upon the hinge line.

Loc. *Gorllwyn and Goleugoed, Caermarthenshire; Berwyns.*

*Orthis triangularis*, Pl. 20. f. 17. Triangular, rounded in front, convex, finely radiated. Length $4\frac{1}{2}$ lines; width 5 lines. Found in Volcanic Grit.

Loc. *Marrington Dingle, near Chirbury.*

*Orthis canalis*, Pl. 20. f. 8., & Pl. 13. f. 7 *b*. Also Wenlock shale.

We have here figured casts of the interior, to show how they differ from the allied species in the higher beds of the Upper Silurian Rocks. The specimens are larger than those in the Wenlock shale.

Loc. *In Caradoc Sandstone at Horderley and Whittingslow, near the Caradoc; Moel-y-garth and Gaerfawr, near Welchpool. In Llandeilo Flags at Clog-y-frain; Golden Grove, Caermarthenshire; and at Llampeter-felfrey, Pembrokeshire.*

*Orthis testudinaria?* Dalman, Pl. 20. f. 9. (*Dalm. l. c.* p. 115. t. ii. f. 4. *His. Pet. Suec.*, p. 70. t. xx. f. 11.) Nearly orbicular, with a straight back, radii numerous, unequal in length, granulated; larger (upper) valve very convex, approaching conical, with an incurved beak; the other slightly convex, with a depression along the middle; hinge line nearly as wide as the shell. Length $6\frac{1}{2}$ lines; width 8 lines.

*Orthis canalis* differs from this in being less convex and more finely radiated; the internal structure is also different.

Loc. *Gaerfawr, Guilfield and Moel-y-garth; east and south of the Caradoc, abundant; also at Powis Castle; Mandinam and Golden Grove.*

*Orthis bilobata*, Pl. 19. f. 7. Transversely obovate with a straight back; covered by thin irregular radiating ridges; upper valve concave, with a broad angular elevation along the middle; lower valve very convex, with a deep broad channel along the middle; sides a little produced towards the extremities of the hinge line, rounded. Length 1 inch 2 lines; width about 1 inch 7 lines.

Loc. *Acton Scott, Horderley; and also in the Upper Cambrian Rocks of Bala.*

*Orthis Vespertilio*, Pl. 20. f. 11. Transversely obovate elongated, with a straight back, covered by thin irregular radiating ridges; upper valve slightly convex, with a broad angular elevation along the middle; lower valve convex, with a deep broad channel along the middle; sides angular at the extremities of the hinge line. Length $\frac{3}{4}$ inch; width 1 inch 2 lines.

A less convex shell than the last, but in many points strongly resembling it.

Loc. *From Corton near Clunbury, along the south-east flank of the Caradoc; Acton Burnell and Stevens Hill, Cound; the Maen, Meifod; Trilobite Dingle, Welch-Pool; in Llandeilo Flags, Caermarthenshire; and in the Cambrian Rocks of Bala.*

*Terebratula furcata*, Pl. 21. f. 16. Orbicular, very convex, smooth; beak of one valve much curved; interior marked with several furrows, and a forked channel in the middle. Length and width 4 lines.

Loc. *S. of Bogmine in the Corndon Hills;* (*Caradoc Sandstone.*)

*Terebratula unguis*, Pl. 21. f. 13. Orbicular, very convex, plaited; plaits about 12, sharp and large; beak incurved. Length $5\frac{1}{2}$ lines; width 5 lines.

Loc. *Horderley; Cefn near Welchpool* (*Caradoc.*).

*Terebratula neglecta*, Pl. 21. f. 14. Orbicular? convex, plaited; plaits 17, acute; beaks small. A fragment.

Loc. *Mandinam, Llandovery.*

*Terebratula tripartita*, Pl. 21. f. 15. Transversely oval? convex, plaited; plaits 15 or 20, rugose, often forked; middle much elevated so as to divide the surface into 3 nearly equal parts. Length $\frac{1}{2}$ inch; width 1 inch 2 lines.

Loc. *Goleugoed, Llandovery.*

*Terebratula decemplicata*, Pl. 21. f. 17. Nearly globose, plaited; plaits 10, angular, two of them greatly elevated in the front; beaks small, pointed. Length 4 lines; width $4\frac{1}{2}$ lines.

Loc. *Bransill Castle, Eastnor Park; Ankerdine Hill; May Hill; Prescoed Common, Usk; Hill End Farm, Longmynd.*

*Terebratula pusilla*, Pl. 21. f. 18. Nearly globose, plaited; plaits about 14, sharp, 4 of them elevated in the front. Length and width nearly 4 lines.

Loc. *Cefn Rhyddan, Llandovery.*

*Pentamerus lævis*, Pl. 19. f. 9. (*Min. Con.*, v. 1. p. 76*. t. 28.) The general outline of this shell is nearly orbicular; it is very convex and smooth. The upper or flatter valve is not so perfectly divided into 3 cells as in the *Pent. Knightii.* But the division in the other valve is always very conspicuous. Length about 1 inch; width about $1\frac{1}{4}$ inch, or sometimes larger.

Loc. *The Hollies near Hope Bowdler, Buildwas; Old Storridge Hill, Worcester; Castell craig-gwyddon, Llandovery; Michaelwood Chase, Tortworth.*

*Pentamerus oblongus*, Pl. 19. f. 10. Oblong-oval, depressed, smooth; a few shallow longitudinal furrows are sometimes observable, especially two in the lower (larger) valve, the beak of which is produced. Length $2\frac{3}{4}$ inches; width $2\frac{1}{4}$ inches.

Occurs with *P. lævis* in the upper beds of the Caradoc formation. The edges of the valves are waved by the shallow furrows without deviating from the same plane.

Loc. *The Hollies, Soudley and Norbury, Salop; Castell craig-gwyddon, Llandovery.*

*Lingula attenuata*, Pl. 22. f. 13. Depressed, smooth; front rounded; sides nearly straight; attenuated towards the apex. Length $7\frac{1}{2}$ lines; width 5 lines.

Loc. *Rorington and Meadow Town, Salop; Golden Grove, Caermarthenshire.*

*Euomphalus tenuistriatus*, Pl. 22. f. 14. Discoid, whorls few, round, rapidly increasing in size, crossed by numerous regular striæ; aperture round, equal in diameter to half the width of the shell. Diameter about $4\frac{1}{2}$ lines.

Loc. *Middleton, Corndon Hills.*

*Euomphalus perturbatus*, Pl. 22. f. 15. Discoid, whorls 3 or 4 rounded, smooth. Diameter about 1 inch.

So much are all the specimens distorted, that our description is necessarily meagre.

Loc. *Pensarn, Caermarthen.*

*Euomphalus Corndensis*, Pl. 22. f. 16. Discoid, smooth, whorls about 3, ventricose; aperture transversely oval. Diameter $2\frac{1}{2}$ lines. f. 16 *a.* is magnified. (In Volcanic Grit.)

Loc. *Leigh Hall, at the Northern extremity of the Corndon Hills.*

*Euomphalus funatus*, Pl. 12. f. 20. Ranges from the Aymestry Limestone to the Caradoc Sandstone.

Loc. *Golden Grove; Middleton, Corndon Hills; Old Storridge Hill, Worcester.*

*Pleurotomaria angulata*, Pl. 21. f. 20. A cast of rather more than one whorl, from which it appears to have been a conical shell with angular whorls, and probably a striated surface; the

aperture was nearly round with an angle at its upper part. Diameter 1 inch 4 lines, height $1\frac{1}{2}$ inch.

Loc. *Mandinam, Llandovery.*

*Trochus lenticularis,* Pl. 19. f. 11. Lenticular, smooth, with a sharp edge; whorls three, with a single line round the inner margin. Diameter $1\frac{1}{4}$ inch.

A very flat shell, we have only seen the upper surface.

Loc. *Old Storridge Hill, Worcester.*

*Littorina striatella,* Pl. 19. f. 12. Conical, with a convex base, marked with fine longitudinal lines of growth; whorls 3 or 4, rounded. Height 8 lines, diameter 7 lines.

Loc. *Horderley and Wistantow (Caradoc).*

*Turbo? Pryceæ,* Pl. 21. f. 19. We have only a cast of the interior, composed of one whorl, which is angular in the middle. The shell appears to have been very short with a large aperture and narrow deep umbilicus; the substance thick. Height about $1\frac{3}{4}$ inch, diameter nearly 2 inches. (Collected by Miss Pryce.)

Loc. *Mandinam, Llandovery.*

*Turritella cancellata,* Pl. 20. f. 18. Subulate?, longitudinally striated, carinated; carinæ about 6 to each whorl, unequal, crossed by the numerous striæ. Diameter $6\frac{1}{2}$ lines.

Loc. *Mandinam, Llandovery; Hope Mill, Shelve.*

*Buccinum? fusiforme,* Pl. 20. f. 19. Fusiform, smooth; whorls few, the last with a shoulder near the upper edge; aperture narrow, as long as the spire. Height $4\frac{1}{2}$ inches, diameter 1 inch 11 lines. In Caradoc Sandstone with *Atrypa hemisphærica,* Pl. 20. f. 7., and fragments of the stems of *Crinoidal animals.*

Loc. *Corton, near Presteign.*

*Orthoceras annulatum,* Pl. 9. f. 5. Also Wenlock Limestone and Shale.

Loc. *Goleugoed, Llandovery.*

*Orthoceras conicum,* Pl. 21. f. 21. Conical, smooth; septa near together; siphuncle central, large, cylindrical. Diameter 1 inch 2 lines.

(Occurs in Upper Caradoc with *Pentam. lævis.*)

Loc. *Michaelwood Chase, Tortworth.*

*Orthoceras approximatum,* Pl. 21. f. 22. Cylindrical for part of its length, conical towards the apex, smooth, slightly curved, septa very near together; siphuncle lateral. Diameter $\frac{3}{4}$ inch.

Loc. *Eastnor Park.*

*Orthoceras bisiphonatum,* Pl. 21. f. 23. Septa very numerous, pierced by two siphuncles, one small, very eccentric, globose (inflated) between the septa, the other large, cylindrical, extending from near the small siphuncle to the edge of the septum. Diameter about $3\frac{1}{4}$ inches.

*Orthocerata* with two siphuncles have been observed, but there has always appeared something doubtful about them. See description of Mr. Bright's specimen of *O. annulatum.* In the present instance, however, this structure cannot be questioned.

Loc. *Gorllwynfach, Llandovery.*

*Nautilus undosus,* Pl. 22. f. 17. Discoid, inner whorls exposed; sides largely waved; front flat; septa numerous; aperture oblong.

This specimen is obliquely compressed into an oval form and much resembles *Nautilus compressus* (M. C. t. 38.). The large waves on the sides distinguish it. Diameter $3\frac{1}{4}$ inches, length of aperture $10\frac{1}{2}$ lines.

Loc. *Blaen-y-cwm, near Llandovery.*

*Lituites? Cornu-arietis* (α), Pl. 20. f. 20. Discoid; whorls about 4, close, crossed by numerous, oblique, sharp, slightly raised costæ, mixed with lines of growth. Diameter nearly 2 inches.

Loc. *Corton, Presteign.*

*Lituites Cornu-arietis* (β), Pl. 22. f. 18. This differs from var. α only in having the costæ more distant and regular. Diameter nearly 2 inches.

Loc. *Cefn-y-garreg, near Llandovery, in black schistose beds of passage from the Silurian into the Cambrian Rocks.*

*Bellerophon trilobatus*, var. ?, Pl. 3. f. 16. (In the upper beds of Caradoc Sandstone.)

Loc. *Eastnor Park; Michaelwood Chase (with Pentamerus lævis); north-east of Gaerfawr; Prescoed Common, Usk.*

*Bellerophon acutus*, Pl. 19. f. 14. Compressed, smooth, umbilicated; whorls keel-shaped, acute; umbilicus broad; aperture triangular, longer than wide. Diameter nearly $\frac{1}{2}$ an inch, width of aperture about 2 lines.

Loc. *Horderley.* (In the upper beds of Caradoc Sandstone.)

*Bellerophon bilobatus*, Pl. 19. f. 13. Nearly globose, smooth; aperture two-lobed. Diameter $1\frac{1}{2}$ inch, width of aperture 1 inch 3 lines.

Loc. *Horderley and Wistanstow; Welch Pool; Michaelwood Chase; Tortworth; Berwyns.*

*Tentaculites scalaris*, Pl. 19. f. 15. (*Schloth. Pet.* t. xxix. f. 9 *b*.) Subulate, composed of a series of truncated cones; internal cast of the same form, but even towards the apex. Diameter 1 line.

The truncated cones of which this appears to be formed have their bases directed towards the apex of the shell; so forming a set of steps rather than rings, like the sliding joints of an opera-glass.

It is not possible to distinguish this body from the *Tentaculites* of the Ludlow formation, though it is much more abundant in the Caradoc Sandstone or Upper Member of the Lower Silurian Rocks.

Loc. *South of the Bogmine, Shelve; Eastnor Park; Damory Hill, Tortworth.*

*Tentaculites annulatus*, Pl. 19. f. 16. (*Schloth. Petr.* t. xxix. f. 8; *Cyathocrinites pinnatus* (*Brachia auxiliaria*), *Goldfuss*, vol. i. p. 190. t. lviii. f. 7 ε, ζ.) Subulate, ornamented with rounded rings placed at regular distances; the spaces between them smooth; the interior of the same form as the outside. Diameter $1\frac{1}{2}$ lines.

(In the upper beds of Caradoc Sandstone.)

Loc. *East flank of the Caradoc; Hope Mill, near Shelve; Michaelwood Chase, Tortworth.*

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The generic names of *Leptæna*, *Atrypa*, and *Orthis*, being new to English geologists, their use on this occasion demands an explanation. They are, in fact, subdivisions of the great family of *Terebratula*, which, having been established by Dalman, have been since adopted by many foreign authors; and Mr. J. de C. Sowerby gives the following reasons for sanctioning their introduction among us.

"The generic names *Leptæna*, *Atrypa*, and *Orthis*, have been adopted from *Dalman's* memoirs in the *Stockholm Transactions*, in deference to the opinion of that author. The first of these synonyms (derived from λεπτος) stands in the place of *Producta* or *Productus*, a name to which grammarians have objected.

"The second genus, *Atrypa* (from α privative, and τρυπα), is divided from *Spirifer*, and includes those species which have a short hinge line without a large area, and are either destitute of a foramen or possess only a small triangular one. They are rounded shells, and are not furrowed like the typical species of *Spirifer*; the internal spiral arms are preserved in some species. *Atrypa affinis* and similar striated shells, would form another natural group, in which the internal structure, as well as the general form, is different; for the spiral appendages, if ever they possessed any, do not appear to remain, and there are two short crenated teeth in the hinge; the species of this division have generally been described as *Terebratulæ* by British authors, but they have acute, not perforated beaks."

"The genus *Orthis* (ορθος) is another division of *Spirifer*, no species of which has heretofore been described in England; it is distinguished from *Spirifer* by the long narrow hinge and circular flat form of the striated shells."

"Our genus *Pentamerus* is called *Delthyris* by the Swedes, but we see no reason for altering the name. If we were well assured of the stability of the genus *Delthyris* we should remove to it *Atrypa galeata*, and perhaps one or two other species of *Atrypa*."

In consequence of the name of *Productus* having been changed for that of *Leptæna* since the earlier chapters of the work were printed, the reader must pardon a slight incongruity which is, however, explained by the double synonym in the description of the shells. For *Productus* read *Leptæna*.

## CHAPTER XLVII.

### TRILOBITES OF THE SILURIAN SYSTEM.

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*General view of Trilobites.—Their geological range.—Trilobites of the Ludlow and Wenlock Formations, or Upper Silurian Rocks,* Pl. 7., Pl. 7 *bis.* & Pl. 14.—*Trilobites of the Caradoc and Llandeilo Formations, or Lower Silurian Rocks,* Pl. 23., Pl. 24. & Pl. 25.—*Structure and Affinities of Trilobites.*

THE natural history of the fossil crustaceans called Trilobites is still imperfect. Though unable to remedy this deficiency, I hope to effect my chief object, by presenting correct sketches of such species of these animals as have been found in the Silurian Rocks of England and Wales, and by explaining the order in which they lie in the strata.

These bodies have been noticed by numerous writers from the year 1699, when our countryman Lhwyd or Lloyd first described them, to the present time; including French, Swedish, German, Russian and American authors. Linnæus considered them to be insects, and named a remarkable species *Entomolithus paradoxus*. They were afterwards termed *Concha-Triloba*, and Knorr, applying this description to the whole family, called them Trilobites, under which name they have been generally known. Brongniart had the merit of being the first to render them serviceable to the advancement of geology, not merely by pointing out their place in the animal kingdom and by dividing the family into genera and species, but also by endeavouring to show what species were peculiar to different deposits. My wish is chiefly to carry out the geological views of M. Brongniart, by adapting them to the present state of knowledge; for as at the period when he wrote (1822), no one had attempted to systematize and classify the older fossiliferous rocks, so it was impossible, even for one who like himself, united the powers of a naturalist and geologist, to draw correct inferences concerning the relative age of these fossils.

It is probable that the generic divisions of this family will hereafter be much altered, and that a nomenclature founded on natural characters will be adopted. In the meantime I shall, as far as possible, adhere to that of Brongniart, merely attaching new names to such forms as have not previously been published. Every naturalist is opposed to the unnecessary use of synonyms, and hence in common with French and English geologists, I see no reason for abandoning the well-known term Trilobites, to

adopt that of *Palæades* (from παλαιος, *old*, *ancient*), or to substitute certain generic names for others previously in use, even though proposed by so eminent an author as Dalman[1]. What does science gain by changing the *Paradoxides* of Brongniart, first called *Entomolithus paradoxus* by Linnæus, for *Olenus*, the name of a son of Vulcan, who, together with his beautiful wife Lethæa, was converted into stone? What advantage has Battus over Agnostus? Such terms, derived from the Heathen Mythology, would doubtless have been well received, if M. Dalman had applied them before these forms had received other names; but are inadmissible when, though not conveying new views in natural history, they are put forth to supplant a nomenclature already established. New generic names are only to be adopted, when forms entirely new are discovered.

As, however, our own country abounds with many well-preserved trilobites, so among them some have been found which really require to be generically distinguished; such, for example, are the *Homalonotus* (König), the *Acidaspis* and *Bumastus* (nobis), and the *Trinucleus* (Lhwyd)[2].

Of the place which these animals occupied in the animal kingdom, I will now merely state that naturalists are agreed in considering them to be marine crustaceans, and that Dr. Buckland, combining in his recent Bridgewater Treatise the observations of Audouin, Brongniart, Leach, and other modern authors, has given his view of their

[1] The original work of Dalman is published in the Swedish language, (Trans. of the Stockholm Academy), but it has been translated into German by Engelhart, "Ueber die Palæaden oder die so genannten Trilobiten." Although for the reasons assigned, I have adhered to the terminology of Brongniart, I ought at the same time to state, that the monograph of the Swedish author is one of high merit. In it we find a list of thirty-eight writers upon trilobites, including Linnæus, Lhwyd, Wilckens, Wahlenberg, Knorr, Da Costa, Lehmann, Blumenbach, Schlottheim, Sternberg, Keilhau, Parkinson, Stokes, Guettard, Audouin, Brongniart, Latreille, Dekay, Leonhardt, Bronn, &c. To this long list we may add the name of Goldfuss, who has illustrated the views of Audouin, and imagined that he discovered vestiges of articulated feet attached to the under surface of trilobites.

From the work of Eichwald "*De Trilobitis Observationes*," Casan, 1825, we learn that in the Russian provinces adjoining the Baltic, there is a succession of marly, compact, and crystalline limestones, underlaid by sandstone and shale. Subsequent examination will, I have little doubt, enable us to place the trilobitic rocks of Sweden and Norway as described by Hisinger, Dalman and Keilhau, as well as those of Russia above alluded to, in parallel with our Upper and Lower Silurian Rocks of Britain, although the mineral characters may vary, as indeed they do in our country, when the strata, of the same age, are followed to considerable distances.

Klöden has collected many trilobites in the gravel of Brandenburg, including our well-known species, *Calymene Blumenbachii*, *C. macrophthalma*, *Asaphus caudatus*, and others of our genus *Trinucleus* of the Lower Silurian Rocks, all of which have apparently been drifted from Scandinavia. "*Versteinerungen der Mark Brandenburg*, 1834," a work full of close research.

In alluding to the literature of this branch of natural history, I must lastly mention an interesting German memoir by Dr. Quenstedt in Wiegmann's Archiv, Part iv. 1837., in which the author attempts to establish a new classification of trilobites by their structure. A translation of this sketch is about to appear in the highly useful new English periodical, the Annals of Natural History.

[2] *Trinucleus* is the old name of Lhwyd or Lloyd (spelt Llhwydd p. 217 *ante*), see p. 659.

affinities. This treatise contains, besides, some excellent original illustrations of parts of Trilobites, particularly of the structure of the eyes and the adaptation of those organs to the submarine habits of the life of the animals[1].

Still more recently, M. Milne Edwards has given us some interesting general views concerning the place which these animals hold among crustaceans. After dividing the whole class into certain families, he shows, "that among the *Decapods*, the *Brachyura* are the highest in organization, and these appear to have been the last created, since no fragments have been detected beneath the tertiary rocks, which can, with any certainty, be referred to that great division, whilst in the supracretaceous deposits many different species of them occur. The *Anomoura*, which establish the passage between the *Brachyura* and the lower tribes of *Decapods*, appear in the cretaceous and oolitic rocks, and the *Macroura*, which of all the *Decapods* are the least elevated in the Zoological series, existed in as old a stratum as the muschelkalk. Lastly, he observes, *the Trilobites, a class of crustaceans still lower* in the natural order, abounded in the seas of the Transition æra, and were at those periods the only known representatives of the class of which they form a part[2]."

*Geological distribution of Trilobites.*—Extensive examination of the older rocks has convinced me, that although these animals have a wide range, extending from some of the slaty rocks upwards to the carboniferous deposits inclusive; by far the greater number of Trilobites occur in the Silurian System. Some genera and species are doubtless found in the older slaty rocks; but the Silurian deposits may be called the great centre of their creation, from which we trace them both downwards and upwards, diminishing, however, rapidly in quantity and variety, either in the descending or ascending series. Let us first observe how they are successively developed in descending order, from their highest station, the carboniferous deposits, down to the lowest in which we know them, the Cambrian Rocks. One species of Trilobite is figured by Martin[3] and supposed to have been found in the coal measures near Mansfield, Derbyshire; also a *Limulus* from Coalbrook Dale by Dr. Buckland in his Bridgewater Treatise[4]; and in a memoir on the same coal-field by Mr. J. Prestwich, about to be published in the Geological Transactions[5], four or five other crustaceans will be given. The whole of these fossils are distinct from any species figured in this work.

Passing down to the limestone which forms the base of the carboniferous system, we meet with other species distinct from those of the coal-measures. Several of these are

[1] After the following descriptions were written, but before these pages were finally printed off, Mr. W. S. MacLeay furnished me with some original observations of high value on the structure and affinities of these animals, which, I am confident, will be deemed well worthy of the attention of naturalists. (See end of Chapter.)

[2] See L'Institut, 1837, p. 254.

[3] *Entomolithus monolites*, Martin Petrif. Derb. Pl. 45. f. 4.; *Belinurus bellulus*, König.

[4] Pl. 46''. f. 3.

[5] Vol. v. p. 2.

figured by Martin[1], and others may be seen in the recent publication of Professor Phillips[2]. Though differing from those of the coal-measures, they appear to resemble them in their small size. Some of them have the generic characters of certain Silurian Trilobites, though of completely distinct species. On the whole, however, so far from being characteristic of a deposit, otherwise rich in organic remains, Trilobites are comparatively of rare occurrence in the Carboniferous Limestone.

We next descend through the Old Red Sandstone, in which we have not yet found these crustaceans, though the shield-shaped heads of the singular fishes which specially characterize the central member of this system, were first supposed to be the bucklers of Trilobites; a mistake by no means to be wondered at, if M. Agassiz be right in informing us, that some of these fossils are almost connecting links between crustaceans and fishes. (see p. 595.)

It is only on reaching the Upper Silurian Strata that we enter upon the great "Trilobitic series." In the highest zone or Ludlow Rock, we find that remarkable form the *Homalonotus* (König), so distinct from any individual observed in the overlying groups. This genus is peculiar to the upper formations of the system; the *Homalonotus Knightii* (König), and *H. Ludensis* (nob.), being very characteristic of the Ludlow Rocks, while the splendid species *H. delphinocephalus* (nob.), (*Trimerus delphinocephalus?* (Green)), occurs in the Wenlock Limestone[3]. The *Calymene Blumenbachii* ranges through the Ludlow and Wenlock formations, but is particularly abundant only in the Lower Ludlow Rock and Wenlock Limestone, beneath which we no longer detect it. The well-known and equally abundant *Asaphus caudatus*, extends from the Lower Ludlow Rock to the base of the Wenlock formation. Both of these trilobites are therefore generally characteristic of the Upper Silurian Rocks. The Wenlock formation contains, however, other forms peculiar to itself, such as the *Calymene macrophthalma*, *C. variolaris*, the remarkable new genera *Acidaspis* and *Bumastus* (nobis), two species of *Paradoxides*, the *Asaphus longicaudatus*, &c.

The Lower Silurian Rocks contain three distinct genera, the *Trinucleus*, *Agnostus* and *Ogygia*, and several species of *Asaphus*, all different from those of the Upper Silurian Rocks. In the Caradoc formation the *Trinucleus* is most characteristic. This genus (of which 6 species are here described) pervades the Lower Silurian Rocks, occurring not only in vast abundance in the Caradoc Sandstone, but occasionally also in the underlying flags. The *Entomostracites punctatus*, Wahl., (*Calymene? punctata*, Dalm.), and the *Asaphus Powisii*, (nob.), seem to be peculiar to the Caradoc formation.

Lastly, in the Llandeilo flags and associated schist, we are presented with distinct forms of Asaphi, in the large *Asaphus Buchii*, and the still larger *A. Tyrannus* and others,

[1] Petrif. Derb.

[2] Geology of Yorkshire, vol. ii.

[3] In describing the Dudley tract (p. 492.), I have not distinguished the *Homalonotus Knightii* from the *H. delphinocephalus*; for I had not then carefully examined the specimens, the latter species having only just been discovered. (See subsequent description, p. 652.)

together with the *Agnostus* and *Ogygia* of Brongniart. These, with two or three species of *Trinucleus*, are confined to the lower beds of the Silurian System.

The Cambrian Rocks of the region illustrated in this work, are, as far as I know, poor in Trilobites, the only traces of them yet observed being in the limestone near Bala[1].

Examining these fossils in the order in which they occur in their native beds, we shall perceive, that as each formation is characterized by peculiar species, so these crustaceans are of great value in determining the age of the deposits; for though most of the mollusks and conchifers also differ in the successive formations, still a few species of them range almost from the top to the bottom of the Silurian System, *whilst no example is yet known, of a species of trilobite which is common in the Upper Silurian Rocks, being found in the lower beds of the system.* I shall describe all the Silurian Trilobites with which I am acquainted in this chapter, beginning with those of the uppermost strata, and terminating with the species peculiar to the lowest. In the mean time I offer a list of the genera and species.

[1] I have seen Trilobites in Devonshire, some of which differ in species from any described in this work. When the older or Protozoic Rocks shall have been thoroughly examined in all parts of the British Isles, it is probable that the list of Trilobites will be materially enlarged.

## LIST OF TRILOBITES IN THE SILURIAN ROCKS.

### Homalonotus, König.

*Homalonotus Knightii,* (König), Upper Ludlow, Pl. 7. f. 1, 2 ?.
——— *Ludensis,* (nob.), Upper Ludlow, Pl. 7. f. 3 and 4.
——— *delphinocephalus,* (nob.), Wenlock Limest., Pl. 7 *bis,* f. 1 *a* and 1 *b*.
——— *Herschelii,* (nob.), (Silurian Rocks, South Africa), Pl. 7 *bis,* f. 2.

### Calymene, Brongniart.

*Calymene Blumenbachii,* (Brongn.), Ludlow and Wenlock, Pl. 7. f. 5, 6 and 7.
——— *Downingiæ,* (nob.), Wenlock Limest., Pl. 14. f. 3 *a* and *b*.
——— *tuberculata,* (nob.), Wenlock Limest., Pl. 14. f. 4.
——— *macrophthalma,* (Brongn.), Wenlock Limest., Pl. 14. f. 2.
——— *variolaris,* (Brongn.), Wenlock Limest., Pl. 14. f. 1.
——— ? ? *punctata,* (Dalm.), *Entomostracites punctatus,* (Wahlenberg), Caradoc Sandst., Pl. 23. f. 7 and 8.

### Asaphus, Brongniart.

*Asaphus caudatus,* (Brongn.), Ludlow and Wenlock, Pl. 7. f. 8 *a*.
——— *tuberculato-caudatus,* (nob.), Wenlock Limest., Pl. 7. f. 8 *b*.
——— *longicaudatus,* (nob.), Wenlock Shale, Pl. 14. f. 11, 12, 13 and 14.
——— *sub-caudatus,* (nob.), Ludlow Rocks, Pl. 7. f. 10.
——— *Cawdori,* (nob.), Ludlow Rocks, Pl. 7. f. 9.
——— *flabellifer,* (Steininger), (not figured), Wenlock Limestone.
——— *Stokesii,* (nob.), Wenlock Limestone, Pl. 14. f. 6.
——— *Powisii,* (nob.), Caradoc Sandst., Pl. 23. f. 9 *a*, *b* and *c*.
——— *duplicatus,* (nob.), Caradoc Sandst., Pl. 25. f. 7.
——— *Buchii,* (Brongn.), Llandeilo Flags, Pl. 25. f. 2 *a* and *b*.

*Asaphus Corndensis,* (nob.), Llandeilo Flags, Pl. 25. f. 4.
——— *Vulcani,* (nob.), Llandeilo Flags, Pl. 25. f. 5.
——— ? (*Illænus,* Dalm. ?) *perovalis,* n. s. Pl. 23. f. 7 *a* and *b*.
——— *Tyrannus,* (nob.), Llandeilo Flags, Pl. 25. f. 1 *a* and *b*.
———, (var. *ornata,* nob.), Llandeilo Flags, Pl. 24.

### Bumastus, Murchison.

*Bumastus Barriensis,* (nob.), Wenlock Limest., Pl. 7 *bis,* f. 3 *a*, *b*, *c*, *d*, and Pl. 14. f. 7.

### Paradoxides, Brongniart.

*Paradoxides bimucronatus,* (nob.), Wenlock Limest., Pl. 14. f. 8 and 9.
——— *quadrimucronatus,* (nob.), Wenlock Limest., Pl. 14. f. 10.

### Acidaspis, Murchison.

*Acidaspis Brightii,* (nob.), Wenlock Limest., Pl. 14. f. 15.

### Trinucleus, Lhwyd.

*Trinucleus Caractaci,* (nob.), Caradoc Sandst., Pl. 23. f. 1 *a*, *b*, *c*, *d*, *e* and *f*.
——— *fimbriatus,* (nob.), Caradoc Sandst. and Llandeilo Flags, Pl. 23. f. 2.
——— *radiatus,* (nob.), Caradoc Sandst., Pl. 23. f. 3 *a* and *b*.
——— *Lloydii,* (nob.), Caradoc Sandst., Pl. 23. f. 4.
——— *nudus,* (nob.), Caradoc Sandst. and Llandeilo Flags, Pl. 23. f. 5.
——— *Asaphoides,* (nob.), Llandeilo Flags, Pl. 23. f. 6.

### Ogygia, Brongniart.

*Ogygia Murchisoniæ,* (nob.), Llandeilo Flags, Pl. 25. f. 3 *a* and *b*.

### Agnostus, Brongniart.

*Agnostus pisiformis,* ? (Brongn.), Llandeilo Flags, Pl. 26. f. 5 *a* and *b*.

## TRILOBITES OF THE UPPER SILURIAN ROCKS, (LUDLOW AND WENLOCK FORMATIONS.)

The prominent family distinction of Trilobites, is the division of their abdomen and post abdomen into 3 longitudinal lobes, by two furrows; which character being scarcely perceptible in this remarkable genus, it has been named (by Mr. König) *Homalonotus.*

Homalonotus. The following is the short account first given in "Icones Sectiles," No. 85, from a mutilated specimen, of the distinctive characters of

*Homalonotus Knightii,* (König.), Pl. 7. f. 1 and 2?.

"Testa ovata (?) acuminata: pars anterior sive caput ——?; corpus multiarticulatum, dorso plano (nec trilobo); pars postica s. cauda simplex, acuminata, parva.

"Nominis occasionem præbuit planities dorsi.

"Exemplar hoc unicum insidens lapidis calcarii fragmini, in Herefordiæ Comitatu, non vero in situ, ut ajunt, reperto, pro humanitate sua ad nos transmisit vir ornatissimus, Andreas Knight, Soc. Hortor. Colendor. Præses."

The above generic character was derived from a form very nearly resembling our figure Pl. 7. f. 1.

Owing to the imperfect condition of the specimens, it is difficult to say whether the form f. 2. belongs to the same species.

*Homalonotus Ludensis,* (N.S.) Pl. 7. f. 3 & 4.

Head *ovate-acuminate? ornamented with small tubercles* (f. 3.). Body *imperfectly trilobed by two slight longitudinal depressions marked with tubercular cavities, ribs* 13? Caudal portion (Pygidium) *ribs* 9? *tail a plain prominent boss prolonged to a sharp point.*

I have ventured to separate this species from *H. Knightii,* König, on account of the longitudinal depressions which almost divide the animal into 3 lobes. We have no means of determining the form of the head of *Homalonotus Knightii,* and we can merely refer to the drawings to convey an approximate idea of that member in *H. Ludensis*; for that of f. 4. is much compressed, and that of f. 3. has been mutilated. In the general form of the caudal portion, there is, indeed, no well-marked difference between *H. Knightii* and *H. Ludensis*; and I have ascertained from other specimens, that both species had pointed tails, like f. 4., the square terminations of figs. 1, 2 and 3. being solely due to mutilation.

Loc. The *Homalonotus Knightii* and *H. Ludensis* are very characteristic of the Ludlow formation, and particularly of its upper division, in which fragments of them are found throughout the Silurian Rocks of Salop, Hereford, Worcester, Radnor, Brecknock, &c.

Fig. 1. is drawn from a specimen discovered by the Rev. T. T. Lewis, near Ludlow. Fig. 2. belongs to Mr. B. Bright, and is from the western flanks of the Malvern Hills. Figs. 3. and 4. are from Ludlow. The former is in the Cabinet of Mr. Evans, Hon. Sec. Worcestershire Nat. Hist. Soc.; the latter was found by Mr. Edward Davis of Presteign.

*Homalonotus delphinocephalus,* nob. (*Trimerus delphinocephalus*?, Green), Pl. 7 (bis) f. 1 *a,* 1 *b.*

Head *depressed, ovate-acuminate. Front of head approaching to even, anterior part flat, slightly raised, and marked with indistinct protuberances. Posterior end marked by a deep groove which produces a ridge closely resembling one of the body ribs.* Eyes *prominent, rather small, papillary and truncated. Facial suture* (linea facialis) *curved, apparently dividing the eye in two, and separating the central lobe from the lateral lobes, passes within the raised anterior margin.* Body *composed of* 13 *ribs with intercostal plates, which extend*

*to the end of the ribs. Lateral portions of ribs falciform, and descending abruptly, the points being directed anteriorly.*

Caudal portion (pygidium[1]) *very distinct from the body, ribs* 12, *lateral lobes nearly equal in width to the central lobe.* Tail *smooth and acuminated.*

The genus *Homalonotus* is distinguished from the *Calymene* by the much greater proportional width of its central lobe, as well as by the apparent absence of trilobation and the peculiar structure and form of the head and tail. It is also remarkable in the falciform termination of its lateral ribs or segments.

The suture (linea facialis) which divides the head into 3 parts, and which, according to Dalman and other authors, is a distinguishing feature of many Trilobites, is well developed in the *Homalonotus delphinocephalus,* and is also seen in the *Bumastus Barriensis* (nob.). In the latter, however, this line passes under the anterior part of the head as shown in Pl. 7 *bis,* f. 3 *e.* This suture is rarely seen in our English specimens owing to the nature of their matrix.

The whole of the surface of the *Homalonotus* was scabrous, but this character is best seen in those portions which were apparently least exposed to friction while living, as at the ends of the side lobes, particularly those of the "pygidium"; for on the back or middle lobe the surface is worn into slight indentations. (Fig. 1 *c.* Pl. 7 *bis,* exhibits a portion of the surface of the post abdominal side lobe; f. *d.* a portion of the central lobe, both magnified.)

The smooth parts intermediate between each segment present a different aspect in different specimens, being almost entirely covered by the ornamented portion of the ribs in some (see the 12th and 13th body ribs f. 1 *a* and *b.*), and in others appearing, even in the centre of the body, as considerable ridges nearly half the width of a rib. This sculpture, partially seen in the anterior part of the body of f. 1 *a* and *b.*, and more clearly developed in other specimens of the same species found at Dudley and also in the *H. Knightii* and *H. Ludensis,* Pl. 7. figs. 1, 2, 3 and 4., shows that the animal must have had the power of contracting and expanding by moving the ribs over each other. Thus the lateral termination of these plates is seen to be scabrous, while their central parts over which the ribs worked? are smooth, as may be seen in some sculptured crustaceans which have the power of coiling up their abdomen.

As I can discover no difference between our *Homalonotus* and the American *Trimerus delphinocephalus,* (Green), except in size, (the latter being very diminutive) I have retained the specific name of the American author, while I adhere to the generic name of König, which was applied to bodies of this form before the publication of Dr. Green.

Loc. *Dudley Castle.* (In the upper beds of the *Wenlock Limestone.*) I am indebted to Mr. Blackwell for the loan of the fine fossil Pl. 7 *bis,* f. 1., and also to Mr. John Gray and Mr. Morris of Dudley, for the use of instructive portions of the head, body and caudal portion, which enabled me to describe some of the above-mentioned peculiarities.

*Homalonotus Herschelii* (n.s.), Pl. 7 *bis,* f. 2.

Differs from *H. Knightii, H. Ludensis* and *H. delphinocephalus,* in the *body being covered by strong and prominent tubercles,* and in the *posterior sides of the head being terminated laterally by a double-headed short process.* In all the essential characters of the genus, however, namely, the indistinct semblance of trilobation, the ovate-acuminated head, form and position of the eyes, number of ribs and their falciform terminations, together with the

[1] I have for the most part employed the terms used by Dalman to designate the different parts of the body.

shape of the caudal portion, this fossil is clearly of the genus *Homalonotus,* and approaches very nearly to our English species. This is the only foreign specimen figured in this work, and I have selected it, because it marks the fact, that the eminent astronomer, after whom it is named, occupied a portion of the time he passed in Southern Africa in promoting geological investigation. The fossil was first sent to me by him. It occurs in the range of the Cedar Mountains (Cedar-berg), N. of the Cape colony, where it is associated with other trilobites, one of which is undistinguishable from *Calymene Blumenbachii,* while another approaches very near to *C. Tristani,* and also with certain mollusks, which leave no doubt of the existence in that region of rocks of the same age as our Upper Silurian; namely, *Cucullæa ovata,* Pl. 3. f. 12 *b.,* (passage-beds from the Old Red Sandstone), *Orbicula rugata?, Conularia quadrisulcata, Leptæna lata,* with fragments of *Turbo, Turritella, Crinoidea,* and a new species of *Nucula,* which ought to be named *N. Smithii,* in honour of Dr. Smith, the naturalist and explorer of South Africa, who collected the specimens[1].

CALYMENE, Brongniart.

Gen. Char.—"Corps *contractile en sphère presque hemicylindrique.* Bouclier *portant plusieurs tubercules ou plis, deux tubercules oculiformes réticulés.* Abdomen *et* post abdomen *à bords entiers, l'abdomen divisé en douze ou quatorze articles. Point de* queue *prolongée.*"

*Calymene Blumenbachii,* figs. 5, 6 and 7. (Brongn. Pl. 1. f. 1.) Syn. Dudley fossil, *Entomolithus paradoxus,* Blum.

"*Clypeo rotundato, tuberculis sex distinctis in fronte; oculis in genis eminentissimis; corpore tuberculato.*"

This species has six rounded protuberances on each side of the central lobe of the head, and fourteen articulations in the back. The tail is small, (see f. 7.), and the shell is covered with little round tubercles of unequal size. It may be added that the *Calymene Blumenbachii* generally exhibits a sculpture of the segments somewhat similar to that described in *Homalonotus,* and also has often the appearance of being marked by a row of rather wide, slightly raised, tubercles on each side of the central lobe of the body (one at the end of each rib.). In Pl. 1. f. 1 *c.* of Brongniart, these costal protuberances appear rather as the raised or bent ends of the central segments. In examining a great number of specimens, we find that this feature, though so strongly apparent in our f. 5., is very inconstant; for we detect numerous gradations between the apparently distinct tuberculation in f. 5. and those which are entirely free from it, like f. 6. As the appearance of such tuberculations is most apparent in those specimens which have been coiled up, and is not visible in those which are straight and unfolded, may we hazard a conjecture that the swellings or knots in question are to a great extent the result of torsion and lateral pressure?

Loc. *Ludlow, Dudley, &c.* The splendid specimen, f. 6., is in the cabinet of Mrs. Downing of the Priory, Dudley. The smaller forms, (those usually found), figs. 5 and 7, are from the *Wenlock Shale of Burrington, near Ludlow,* where they were collected by the Rev. T. T. Lewis and myself.

The *Calymene Blumenbachii* occurs both in the Ludlow and Wenlock formations, but most

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[1] In the first part of the 8th vol. of the Journal of the Geographical Society just published, Capt. Alexander thus alludes to the Cedar Mountains:—"The principal rock of the higher parts (5000 feet), appears to be an ash-coloured, quartzose sandstone; the secondary range contains many marine petrifactions, shells and fish, at a height of 2000 feet above the sea."—p. 3.

abundantly in the latter. It is, however, generally characteristic of the Upper Silurian Rocks. Together with the *Asaphus caudatus*, it is one of those trilobites which have the widest geographical range, occurring in North America, Norway, Russia, and in various parts of France, Germany, and Poland. To these localities I may add Southern Africa, where, as above stated, it has been found associated with the *Homalonotus Herschelii*, and other fossils of the Upper Silurian Rocks.

ASAPHUS, Brongniart.

Gen. Char.—" Corps *large et assez plat; lobe moyen saillant et très distinct.* Flancs *ou lobes latéraux ayant chacun le double de la largeur du lobe moyen.* Expansions *submembraneuses depassant les arcs des lobes latéraux.* Bouclier *demi-circulaire portant deux* tubercules oculiformes réticulés ? Abdomen *divisé en huit ou douze articles.*"

*Asaphus caudatus*, f. 8*a*. Brongn.

This figure is given to show the form of the tail of the species figured by Brongniart and other naturalists as the true *Asaphus caudatus*, which differs from our large figure 8, in exhibiting *a central lobe without tubercles, a very distinct separation of the abdomen from the caudal portion, and the termination of the lateral ribs of the former in points.*

Loc. In great abundance throughout the Upper Silurian Rocks, (*Ludlow* and *Wenlock* formations), being nearly as prevalent as the *Calymene Blumenbachii.*

*Asaphus tuberculato-caudatus*, (n.s.), f. 8.

Spec. Char. Shield *anterior part oval, posterior strongly margined, sides extended to the sixth rib and terminating in sharp points.* Head *covered with small tubercles, central lobe having* 5 *protuberances,* 4 *of which, somewhat resembling ribs, lie between and below the eyes; the fifth is large, expands laterally, and advancing to the anterior edge of the shield is marked through half its length by a furrow.* Eyes *crescent-shaped, conical, composed of many lenses*[1]. Body, *each rib of central lobe ornamented by a large tubercle on either side.* Caudal portion, *ribs tuberculated like those of the body, terminated by a sharp tail.*

I have ventured to separate this species from the *A. caudatus*, Brongn., because every rib of the central lobe of the body and caudal portion (in all twenty-three) is flanked by a large stud or tubercle. It further seems to differ in its head being enriched with tubercles, and in having an additional frontal protuberance; while the body and caudal portion which are almost inseparable in our species, are very sharply divided in *A. caudatus*, Brongn.

This species resembles *A. limulurus* of the United States, in having a small tuberculated central lobe; but the latter has a fine pointed tail like our *A. longicaudatus*, Pl. 14. figs. 11, 12, 13 and 14, and its ribs terminate laterally in reflected spines. (See Green's Monograph, p. 48. and cast 16.)

Loc. *Dudley*.

*Asaphus* (*Olenus*) *flabellifer?*, Steininger; Trans. Soc. Geol. de France, tom. i. pl. 21. f. 10.

The caudal termination of this fan-tailed species, found by Dr. Lloyd, in the Wenlock Limestone, is in the Museum of the Ludlow Society. A good drawing of it was sent to me by Professor Phillips, and I have since seen the original. It somewhat resembles *A. laticauda*, Brongn. Pl. 3. f. 8., and also *A. laciniatus*, Dalm. t. 6. f. 1., but is most probably identical with the *A.* (*Olenus*) *flabellifer* of Steininger from the Eifel. Although I have not figured this curious fragment, I may observe that similar caudal remains are said to occur in South Devon.

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[1] The use of these lenses in horizontal vision, and of which there are at least 400 in *Asaphus caudatus*, is beautifully described in Dr. Buckland's Bridgewater Treatise, p. 399., and has been before adverted to p. 647.

Steininger has not published a specific name, but I learn from M. de Verneuil that he has recently assigned to the fossil the above descriptive term.

*Asaphus Cawdori,* (n.s.), f. 9.

*Asaphus subcaudatus,* (n.s.), f. 10.

These post-abdominal terminations of trilobites differ from any published species with which I am acquainted, and are probably portions of an *Asaphus.* I have named No. 9. after the Noble Earl who discovered it.

Loc. *Fresh-water East, South Pembroke,* where they were both found in Upper Silurian Rocks by the Earl of Cawdor.

The species No. 10. has been also observed by Mr. Lewis in the Aymestry limestone near Ludlow.

N.B. Other *Asaphi* which occur in the Wenlock, Caradoc and Llandeilo formations, are described in the subsequent pages.

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## TRILOBITES OF THE UPPER SILURIAN ROCKS (*continued*).

### PLATE XIV.

*Calymene variolaris,* f. 1. Brong. (var.?)

Spec. Char.—*Clypeo rotundato, lobis inflatis valde tuberculatis, angulis externo-posticis in mucronem productis* (Brongn.).

The prominent distinction of this species consists in *the highly ornamented pear-shaped central lobe of the head with a swelling front.*

M. Brongniart also remarks, "that the numerous small tubercles with which the animal is covered have a small aperture near their summit, similar to the tubercles to which the spines of *Cidaris* are attached," a distinction which I have never observed. Can the remarkable prolongation of the lateral edges of the buckler, given in the figure of Brongniart, Pl. 1. f. 3 A., have been obliterated in our specimen, or is the latter a variety?

Loc. *Wenlock Edge and Dudley.* The *Calymene variolaris* is not very common. It is (as far as I know) peculiar to the Wenlock formation.

The specimen figured is from the cabinet of Mrs. Downing.

*Calymene macrophthalma* (Brong.), f. 2. Brongn. Pl. 1. f. 5 A, B and C.

Head *round and plain in central division.* Eyes *very large and protuberant, occupying the greater portion of the sides or cheeks and composed of many lenses. The back,* M. Brongniart remarks, *has* 12 *or* 13 *articulations and is neatly separated from the short pointed tail.*

Loc. *Wenlock and Dudley,* but, like the *C. variolaris,* less frequently than the *Asaphus caudatus* and *Calymene Blumenbachii.*

*Calymene? Downingiæ* (n.s.), f. 3. Buckl. Bridgw. Treat. Pl. 46. f. 5.

Head *ovate-acuminate, central part divided on each side by* 3 *transverse furrows into tubercles.* Eyes *rather smaller than in* C. macrophthalma, *but similarly ornamented.*

I have separated the *Calymene macrophthalma,* Brong., into two species, believing that his figure, Pl. 1. f. 4 B., is our common, large-eyed species, and that his f. 4 A. of the same Plate, judging from the ovate-acuminate head and the tubercles on the forehead, is our *C. Downingiæ.* The last-mentioned species is infinitely rarer than that to which I would restrict the name of *macrophthalma.* That species is at once recognized by its bald, plain, rounded head, as is

well exposed in the drawings of Mr. C. Stokes. (See Brong. Pl. 1. f. 5 A, B and C.) I have named this species after Mrs. Downing, to whom I am indebted for the loan of it.

Loc. *Dudley*.

*Calymene tuberculata*, f. 4.

This species has usually been referred to *C. macrophthalma*, from which it differs in having *a more elevated front and a more tuberculated central lobe of the head.*

Loc. *Dudley*. It occurs also near St. Petersburgh.

Fig. 5., fragment of a trilobite from the Wenlock Shale, probably undescribed.

*Asaphus Stokesii* (n.s.), f. 6.

Head *oval, shield much prolonged on the sides and central lobe ornamented at the base with* 3 *tubercles.* Body *with* 9 *or* 10 *articulations;* caudal portion *nearly semicircular; central lobe slightly pointed.*

This beautiful little specimen, which belongs to Mr. Charles Stokes, is clearly distinguished from every published species by its general form and by the curved and projecting sides of the shield.

I have real pleasure in naming this species after so accomplished a naturalist as Mr. Stokes, who it is to be hoped may soon prepare a monograph of fossil crustaceans, concerning which he possesses so much valuable knowledge.

Loc. *Dudley*.

*Asaphus longicaudatus* (n.s.), figs. 11, 12, 13 and 14.

This trilobite differs essentially from the *A. caudatus*, Brong. Pl. 3. f. 9., or the *A. mucronatus*, Dalm. Tab. 2. f. 3., *both in general form and in the exceeding slenderness and length of the tail. There is, however, another important distinction in the rim or outer edge of the buckler, being produced anteriorly in a large protuberance.*

The most entire of our specimens (f. 12.) is a good deal mutilated in the body, and hence it is impossible to describe that member accurately; but the post abdomen, the most distinguishing portion of the animal, has 15 well-pronounced articulations (the *Asaphus caudatus* having 10 to 11 only) from which the slender and pin-like tail extends in one specimen even to $2\frac{1}{2}$ inches.

Loc. The *Asaphus longicaudatus* is usually found in the lower part of the Wenlock formation.

In the specimen f. 12. (from the shale *under the Wenlock Edge, near Wistanstow, Salop*), the shelly matter, being partially preserved, indicates the extreme thinness of the covering of this crustacean.

Fig. 11 is from the *Malverns* (cabinet of Mr. Bright) and figs. 13 and 14 are from *Dudley*, &c.

Bumastus, Nobis. (*Bumastus*[1].)

Gen. Char. *Pars anterior* capitis rotundato-convexa, subæqualis: oculis lunatis, glabris, remotis. *Pars costalis s. corpus* sulcis longitudinalibus vix apparentibus, costis decem. *Pars posterior* maxima, rotundato-tumida, æqualis. [*Obs.* Omnes testæ partes ultro citroque, linearum sulcatarum subtilissimis ambagibus punctulisque confertis, insignitæ.]

*Bumastus Barriensis* (n.s.), Pl. 7 *bis.* f. 3 *a, b, c* and *d.*; Pl. 14. f. 7 *a* and *b.*

Head *round* (*bombé*) *in front, margin raised, oculine protuberances large, surrounded by a depression on the edge of which, over the eyes, two small ovate prominences; in advance of the eyes and towards the margin two slight hollows.* Eye *approaching to semilunar, apparently*

[1] βούμαστος, uva eadem quæ bumamma, genus uvæ crassioris rotundique acini; a kind of large grape. Virg. Georg. ii. 102. Colum. iii. 2.

*smooth.* (See Pl. 7. f. 3 *a* and *b*.) *The facial suture* (linea facialis) *traverses the oculine protuberances, separates the upper portion of them from the eye, and passes under the margin.* (See Pl. 7 *bis.* f. 3 *b**.) Body *with no true longitudinal furrows; central lobe only just perceptible by very slight depressions in the body only. Ribs* 10, *those of the lateral lobes terminating in recurved blunt ends.* Caudal portion *round and smooth without a trace of trilobation.* (See Pl. 14. f. 7.) *Surface of the whole animal* (*testa*) *covered by extremely thin, apparently imbricated lamellæ, the edges waved or vermiform, the intermediate spaces studded with minute dots.* (See magnified portions of the eye and head, Pl. 7 *bis.* f. 3 *c* and *d.*) Where exposed to friction during the life of the animal these markings are removed.

This remarkable crustacean has been hitherto known in England as the Barr trilobite, having been found at the Hay Head lime works, near the village and beacon of Barr in Staffordshire. A very large specimen of it, 5 inches long by $3\frac{1}{6}$ inches wide, has been lithographed at Birmingham, and the species has been figured under the English name above stated by Mr. F. Jukes and Mr. J. Sowerby, in Loudon's Mag. Nat. Hist. vol. ii. p. 41., accompanied by a wood-cut.

I formerly supposed that, from its equally balanced extremities, this crustacean belonged to the genus *Isotelus* (Dekay), p. 215., but since the earlier chapters of this work were printed, I perceived that the English fossil was excluded from the American genus by the absence of distinct trilobation in the body, and of any trace of such divisions in the caudal portion, by having 10 instead of 8 ribs, and by other essential differences.

I next observed, that although agreeing with the *Illænus* of Dalman in the number of ribs, that genus differed from our fossil in having the head plain and without protuberances, eyes strongly reticulated, body distinctly divided into 3 lobes, the longitudinal depression being extended into the head and caudal portion, and the lateral ends of the ribs sharp. Though our fossil approaches to *Nileus Armadillo*, Dalman, in the almost entire absence of longitudinal trilobation, that genus is very distinct from ours, by having eight ribs only, which terminate in points, a plain head, and very large reticulated eyes. Again, I was once disposed to think that the mutilated specimen, without a "pygidium" figured by Eichwald as *Cryptonymus Rosenbergii*, De Tril. Obs. Casan, Pl. 3. f. 3 *a* and *b*., might be identical with our species, but on receiving (while these pages were printing) the rare work of Pander, published subsequently to that of Eichwald but unknown in England, and in which all the transition fossils of the neighbourhood of St. Petersburgh are elaborately described, I ascertained that the *Cryptonymus Rosenbergii* is the *Illænus crassicauda,* Dalm., a fossil quite distinct from our specimen[1].

I have therefore ventured to consider this trilobite a new genus, and to name it *Bumastus,* the specific name being derived from the locality where it was found. The peculiarity of structure of its surface has not I believe been noticed by the Swedish or Russian authors as belonging to any trilobite described by them, nor can I detect it in a specimen of *Illænus crassicauda,* collected by M. Brongniart near Linkoping in Sweden, and lent to me by Mr. C. Stokes, though a specimen supposed to be from Russia, apparently identical with our *Bumastus Barriensis,* and having precisely the same surface, was pointed out to me in the British Museum by Mr. König. Being acquainted with one form only of *Bumastus,* it is possible

[1] The work of Pander, "*Beiträge zur Geognosie des Russischen Reiches,* 1830," was obligingly sent to me by the Baron de Meyendorf, through my friend M. de Verneuil. I shall allude to this work again at the conclusion of this chapter.

that these markings ought to constitute a specific difference only, for I am aware that this sort of sculpture can seldom be a generic distinction. I have merely added them to the generic character provisionally. They are seen in specimens from Staffordshire as well as in the beautiful head Pl. 7 *bis*. f. 3. belonging to Mr. B. Bright, which was found on the western slopes of the Malvern Hills. The under surface of this head (Pl. 7 *bis*. f. 3 *b*.) also shows how the fine furrows (lines of growth ?) conform separately to the outline of the different parts of the head.

Loc. *Hay Head Lime Works, near the village and beacon of Barr, Staffordshire; near Brand Lodge, Malvern Hills, the residence of Mr. Bright, near Presteign.*

PARADOXIDES Brongniart. *Entomostracites paradoxides* (Wahlenberg). *Olenus* (Dalman).

Gen. Char.—"Corps *déprimé non contractile.* Flancs *beaucoup plus larges que le lobe moyen.* Bouclier *presque demi-circulaire; trois rides obliques sur le lobe moyen. Point de* tubercules, oculiformes. Abdomen *a douze articulations.* Arcs des flancs, *abdominaux et post-abdominaux, plus ou moins prolongés hors de la membrane qui les soutient.*"

Brongniart established this genus, and I therefore retain his name. Without entering into a detail of characters, it may always be recognised by the ends of all the lateral ribs terminating in deflected points, some of which extend in spikes beyond the tail.

*Paradoxides bimucronatus* (n.s.), f. 8.

Our specimen differs essentially from any published by Wahlenberg, who first figured the genus, or from the figures of Brongniart or Dalman, in having a *sharp, two-pronged tail.* The large, incurvated, flanking spines are also wider apart than in the *P. Tessini*, Brong. Pl. 4. f. 1. (the *Olenus Tessini*, Dalm. tab. 6. f. 3.), which it more nearly resembles.

Fig. 9. is probably the body of *Paradoxides bimucronatus*, f. 8., being found in the same slabs of limestone. The lateral lobes of the body present curiously sculptured plates, *that almost give it the appearance of being divided into five lobes.*

On examining the structure of the segments of trilobites, we find a great variety of sculpture. The sculpture in f. 9. is very remarkable. We may observe, that the further the rough sculpture reaches from the middle lobe, the less the animal must have had the power of moving and coiling itself up. See *Homalonotus Ludensis*, Pl. 7. f. 4. and *Calymene Blumenbachii*, Pl. 7. f. 6. A reference to a lobster's tail will best explain this sort of structure, which is strongly developed in our f. 9. and has been alluded to in p. 653.

Loc. *Wenlock Limestone of the Malvern Hills*, where it was found by Mr. B. Bright.

*Paradoxides quadrimucronatus* (n.s.), f. 10.

This beautiful little species, from the cabinet of Mr. Stokes, differs from the *P. spinulosus*, Brongn. Pl. 4. f. 2. (*Olenus spinulosus*, Dalm. tab. 6. f. 4.) both in general form and in having a four-pronged instead of a simple rounded tail.

Loc. *Dudley.*

ACIDASPIS, Nobis. (*ακις, mucro, ασπις, scutum.*)

Gen. Char.—Capitis *scutum* marginatum, antice subtruncatum, trituberculatum: tuberculo medio postice in *mucronem* desinente.

*Acidaspis Brightii* (n.s.), Pl. 14. f. 15.

Although most unwilling to multiply names, the very remarkable form of the head or shield of this trilobite, the posterior end of its central lobe projecting over the body in the form of a stomacher, and rendering it totally distinct from any published figure, induces me to propose it as a new genus.

The raised and beaded, if not toothed rim of the buckler is also curious, and may serve to distinguish this from any species of the genus *Acidaspis* which may hereafter be found. I dedicate it with much pleasure to Mr. B. Bright, to whom the original belongs, and the liberal use of whose rich cabinet has assisted me so materially to illustrate this work.

Loc. *Wenlock Limestone of the Malvern Hills.*

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## TRILOBITES OF THE LOWER SILURIAN ROCKS (CARADOC AND LLANDEILO FORMATIONS).

TRINUCLEUS, Pl. 23. figs. 1 to 6. (*Lhwyd Ichnogr. Lith. Brit. Epist.* t. 23.) CRYPTOLITHUS, Green. *Asaphus granulatus ?*, Dalm.

Gen. Char. (Nobis.)—*Caput* obtusum, *scutum* marginem versus punctulis concavis ex ordine collocatis ornatum, trilobum : lobis rotundato-protuberantibus, medio lateralibus minore.

*Corpus* breve, 5—7 costatum : costis lateralibus rectis.

*Pygidium* trilobatum breve.

Seeing that these distinctions, as above defined, prevail in several species of trilobites, I have formed them into a new genus under an old name assigned to one species of an animal of this form by Lhwyd.

*Trinucleus Caractaci* (n.s.), figs. 1 *a, b, c, d, e* and *f*.

Spec. Char.—*Marginal pores of the shield in concentric rows* (5 *and* 6) *in the front, on the sides scattered and terminated laterally by a plain, slender, pointed cheek or spike, which extends beyond the body. Caudal furrows,* 5 *on each side. Tail obtusely mucronated.*

The marginal pores magnified, are seen (in f. 1.) to penetrate the shield, a peculiarity so great in crustaceans, that if Lhwyd had not originally figured one of this genus as *Trinucleus*, and Green had not subsequently called it *Cryptolithus*, I might, as before stated, p. 217, have proposed the generic name of *Tretaspis*, (perforated or deeply sculptured shell). The lateral spike of the buckler is found in well-preserved specimens only, or those which have been deposited in finely levigated materials, figs. 1 *c* and 1 *e*. (Our species is quite distinct from the *Cryptolithus tessellatus* (Green) of N. America in having 5 or 6, instead of 3, rows of marginal sculpture on the shield, and also by the lateral spikes of the buckler.)

Loc. This fossil is so abundant in the Caradoc formation that I have named it *Trinucleus Caractaci*. The specimens figured, as well as those of figs. 2 and 3, were collected by myself in reddish and blackish, sandy shale, in a little dingle west of *Welch Pool Church*. The same species, however, abounds in the impure limestone and sandstone on the eastern flanks of the *Caradoc Hills*, in the *Meifod Hills*, Montgomeryshire, and occasionally, though rarely, in the upper beds of the *Llandeilo flags* (*Caermarthenshire*). It has also been found with other Silurian fossils in *Ireland* (*eastern part of Tyrone*) and has very recently been figured to illustrate a description of the structure of that region by Capt. Portlock, R.E. (See Ordnance Survey of Ireland, vol. viii. Pl. 1, 2 and 3[1].)

[1] The figs. 6. Pl. 1. and f. 8. Pl. 2. of Capt. Portlock are the forms I should refer to my species *Trinucleus Caractaci*, though not with absolute certainty, seeing that the specimens are mutilated. I may add, that among these Irish specimens, f. 9. Pl. 2., resembles the *Illænus? Corndensis*, Pl. 23. f. 7., while f. 7. Pl. 2. o. the Ordnance Survey is not unlike the *Calymene ? punctata* Pl. 23. f. 8., though the former has no punctures.

*Trinucleus fimbriatus* (n.s.), f. 2.

*Marginal pores in diverging rows in the front of the shield; on the sides scattered; lateral spike of the buckler divergent from the body. Caudal ribs* 12 *on each side.*

This is probably the same species figured by Lhwyd, Epist. 1. p. 9. t. 23. I have never found it entire, but the caudal extremity occurring in the same fragment of rock with the buckler, and both agreeing with the figure of Lhwyd, I have considered them as parts of the same species. The simple fimbriated rim of the buckler distinguishes this species from the others[1].

Loc. *Near Welsh Pool and Builth.*

*Trinucleus radiatus* (n.s.), figs. 3 *a* and *b*.

*Marginal pores arranged on the front of the head in* 1 *or* 2 *rows; on the sides in long radiating lines. Buckler square, lateral spikes short.*

Although fragments of the head only have been found, there can be no hesitation in referring them to the genus *Trinucleus,* while the radiating lines and general outline of the buckler are very distinct from those of any other species.

Loc. *Trilobite Dingle, Welsh Pool; Caradoc and Meifod Hills, &c.*

*Trinucleus Lloydii* (n.s.), f. 4.

*Marginal pores on the front of the head in several rows; on the sides scattered. Buckler round, with lateral spikes advancing beyond the body, which is composed of* 5 *ribs.*

*Caudal portion semicircular. Tail obtuse, ribs on each side terminating in hooked points.*

This species is at once distinguished from other *Trinuclei* by the vast length of the buckler, which with the pendent cheeks advancing to the posterior extremity of the animal, constitute a peculiarity not observed in any other published trilobite.

Loc. This beautiful and rare species was found in the black flag of *Blaen-dyffrin-garn, near Llangadock,* by the Rev. Henry Lloyd of Tan-yr-alt. The rock is one of the superior beds of the Lower Silurian Rocks, and owes its hard character to the boss of trap by which it is thrown off.

*Trinucleus nudus* (n.s.), f. 5.

*Three nuclei of the head without the ornamented buckler.* It differs from *T. fimbriatus* in the number of caudal ribs, (9 or 10 instead of 12,) and in the outline of the head which is more oval.

Loc. *Gwern-y-fad, near Builth in Llandeilo Flags; the Gilwern Hills, near Llandrindod.*

*Trinucleus? Asaphoides* (n.s.), f. 6.

*Three nuclei less distinct than in the other species, and general form approaching to that of Asaphus;* hence its name.

Though distorted, this little specimen is interesting, in showing the passage from the *Trinucleus* to the *Asaphus,* the leading distinction of a sculptured shield being scarcely perceptible.

Loc. *Near Builth.*

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Judging from these specimens, I should infer that they belonged on the whole to the Lower Silurian Rocks. The Graptolite and the Orthoceratite, figured Pl. 3., are probably from the lowest beds of the Upper Silurian Rocks.

[1] Brongniart has figured fragments of this genus, from drawings of Mr. Stokes, Pl. 4. figs. 5, 6 and 7., but assigns no name to them, referring them with doubt to *Asaphus cornigerus,* from which, however, they are distinct.

It would appear from the observations of Bigsby, and also from those of Dr. Green, that the genus *Trinucleus* is very abundant in North America. I have not yet had an opportunity of comparing good specimens, though it is probable that one of the specimens found by Dr. Bigsby, near Montmorenci, and in the collection of Mr. C. Stokes, is our *Trinucleus fimbriatus*, f. 2., called *T. Bigsbii*, p. 397. (See Geol. Trans. vol. i. p. 196.)

*Calymene? ? punctata, f.* 8 *a, b.* (Dalm. Pl. 2. f. 2 *a, b.*) *Entomostracites punctatus*, Wahl., (Brongn., Pl. 3. f. 4.)

The caudal portion of this trilobite, identical with the figures of Wahlenberg, Brongniart and Dalman, is abundant in the Caradoc Sandstone. As neither the body nor head of the animal have yet been found, it is impossible to fix the genus[1].

The old name of *Entomostracites* was also applied by Wahlenberg to the genus *Trinucleus*, one species of which is copied from that author into Brongniart's work, Pl. 3. f. 7., under the name of *Entomostracites granulatus*.

Loc. *Michaelwood Chase, Tortworth; Caradoc and Meifod Hills.*

*Asaphus Powisii* (n.s.), f. 9. (*a, b, c.*)

Head *having a large round mamillated front, two prominent lateral divisions. Central lobe of the body very wide, and separated by a raised margin from the lateral lobes, which have obtuse ends.* Eyes *composed of many minute lenses arranged in hexagons.* Caudal portion *semicircular, and circumscribed by a broad band.* (*The eye is not seen in the larger figure, but is partially represented in* f. 9 *b.*)

I have named this splendid new species of trilobite after the noble family in whose demesnes in Montgomeryshire it occurs.

Loc. *In the upper beds of the Caradoc formation at Cheney Longville, Salop, and in shale of the same age at Welch Pool, Montgomeryshire.* The fragment f. 9 *b.* was found by Mr. Lewis and myself in the calcareous or upper bed of the Caradoc formation, on the banks of the Onny, near Cheney Longville.

The other portions figured were found by myself in "the trilobite dingle," Welch Pool, to which I have already adverted, (see p. 217 and 303.)

ILLÆNUS (Dalman).

*Illænus? perovalis* (n.s.), figs. 7 *a* and *b*.

*Elongated oval form; central lobe of the body slightly prolonged into the caudal portion. Blind?*

From its equally balanced extremities, this animal was supposed to belong, as mentioned p. 215., to the genus *Isotelus*. It appears, however, to differ from every published species, though it most nearly approaches *Illænus*, Dalman, from which, however, it must differ if really blind.

Loc. *Flanks of the Corndon (or Cornden) mountain near Shelve, on the borders of Salop and Montgomery,* where I found it in Lower Silurian Rocks much altered by igneous action. Other trilobites from this tract are figured in Pl. 25. figs. 4 & 5.

*Asaphus duplicatus*, nob. Pl. 25. f. 7.

Body 13 *to* 14? *ribs, central lobe very small and prolonged to a sudden termination in the*

[1] A small elongated but mutilated *Calymene*, distinct from *C. Blumenbachii* and nearly resembling *C. Tristani*, Brongn., was found at Cefn Rhyddau near Llandovery, by Mr. W. Williams, and at Cefn-y-garreg; also near that place by myself, in both instances in Lower Silurian Rocks.

*tail.* Caudal portion *broad and very obtuse, lateral lobes convex, ribs* 10? *each having an additional furrow near its posterior edge.* (The specific name is taken from the last-mentioned feature.)

Loc. *Wilmington* near Marton, Salop. In sandy, black shale which rises from beneath the Upper Silurian Rocks of the Long Mountain. A rare species found by myself.

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## TRILOBITES OF THE LLANDEILO FLAGS.

### PLATES XXIV. AND XXV.

*Asaphus Buchii,* Pl. 25. f. 2. Brongn., Pl. 2. f. 2. *a, b.*

"Corpore ovato, antice obtuso; pars caudæ membranacea ad marginem longitudinaliter striata."—Brongn.

M. Brongniart further describes this *Asaphus, as having an ovate form, the head being at the larger end; the central lobe of the buckler pretty distinct, and terminating anteriorly in a slightly tuberculated point.*

The lateral lobes of the head described by Brongniart as triangular, are more neatly defined in our specimen, and show a curved outline of the posterior margin, the eye being placed near the lobe centre of the f. 2 *a* and 2 *b*. In Brongniart's specimens the outer rim of the buckler is indistinctly marked. In our figure it is seen to advance beyond the centre of the body, and to terminate in a fine point. The costal arches near the ends of the lateral lobes of the body are double (see f. 2 *a.*) The central lobe is nearly pyramidal. The coriaceous membrane which covered the ends of the caudal ribs, is striated parallel to the margin. The transverse studs, marking the prolongation of the caudal ribs beneath the coriaceous membrane, is a character much insisted on by Brongniart, Pl. 2. f. $3b^1$. I may here observe, that after the plates had been engraved, Lord Cole lent me a specimen of *Asaphus Buchii* (from Builth), rather larger and having a more perfect head and buckler than that which I have figured (from the collection of Mr. C. Stokes); this specimen further exhibits the termination of the body ribs in deflected points, and the fine striation of the external coriaceous membrane is beautifully exposed. The specimen figured is from the cabinet of Mr. Stokes.

Loc. *Abundant throughout the Llandeilo formation, portions of it occurring in numberless quarries in Caermarthenshire, Pembrokeshire, Radnorshire, Brecknockshire, Shropshire, east flank of the Berwyns, &c.*

It is said to occur in Norway, Russia and America.

*Asaphus tyrannus,* n.s. Pl. 25. f. 1 *a b.*, and Pl. 24.

Spec. Char.—Head, *posterior margin of buckler extending in a short spike to the third segment of the body.* Body, *central lobe very broad, and contracting suddenly as it passes into the caudal portion. Ribs* 8, *subdivided by intermediate plates which terminate obtusely.* Caudal portion *elongated and pointed; ribs deflected to the tail at an acute angle.*

This trilobite thus differs essentially from *Asaphus Buchii.*

The specific distinctions are all visible in the figures, though the peculiar form of the head and buckler of *Asaphus tyrannus* is still better seen in an unfigured species recently sent to the British Museum by the Earl of Cawdor.

*Asaphus tyrannus,* varietas *ornata,* Pl. 24.

I venture to consider the forms in Pl. 25. f. 1?, and Pl. 24., as belonging to the same species,

because the central abdominal lobe in each seems to bear precisely the same relative proportions to the flanks or sides of the animal, and to exhibit the same sudden contraction towards the tail.

The large specimen, Pl. 24., presented to me by the Earl of Cawdor, must, however, be considered a variety on account of its ornamented surface; and I have therefore named it *Asaphus tyrannus*, var. *ornata*. Although merely a hollow impression, which has been long exposed action of the weather, it gives a clear idea of the general form and size of the animal, which was nearly one foot in length.

The *Asaphus tyrannus* is equally abundant with the *A. Buchii* in the Llandeilo flags of Caermarthenshire and Pembrokeshire (pp. 357, 397). It is usually found without the head, as in Pl. 25. f. 1.; but even in that condition, the observer can never fail to distinguish it by the great width of its central lobe and the pointed tail, which is strongly contrasted with the round termination of *A. Buchii*. The latter is of smaller size; the largest specimen I have ever seen not exceeding five inches in length, while the new species is often six or seven inches long. This circumstance induced me to give it the name of *tyrannus*, in order to mark this species as the chief being of his race, during the period when the Lower Silurian Rocks were accumulating.

The noble specimen *A. tyrannus*, var. *ornata*, is now placed in the British Museum, illustrated by casts taken from the intaglio figured. It does not appear that any writer has alluded to a specimen of this magnitude; but Professor Phillips informs me, that in a recent tour in Norway he sketched the outline of one in the rock, of about the same size, and apparently of the same species.

Loc. *Banks of the Towy, near Llandeilo; and in Dynevawr Park and Golden Grove; Clog-y-frain, near St. Clears, Caermarthenshire; Llampeter felfrey, Pembrokeshire.*

*Asaphus Corndensis*, (n. s.), Pl. 25. f. 4.

This species approaches near to *Asaphus Buchii*, Brong., but is distinguished from it by *the greater length of the lateral spinose terminations of the buckler, which advance posteriorly to the penultimate or seventh rib of the body, and also by their terminating obtusely.*

Loc. Found by myself in dark-coloured flagstone, alternating with volcanic grits, near *Middleton, on the north-western flank of the Corndon Mountain.* I have named it after the dominant feature in a tract so interesting from its varied geological phænomena. (See Chapter 22.) The same fossil is associated with *Asaphus Buchii*, *A. tyrannus*, and other species too imperfect to be named, at Rorrington and Meadowtown, in the north-north-eastern prolongation of the same band of Llandeilo flags, and also in the undulating strata of the same age in the adjacent mining tract of Shelve, Hope Mill, &c.

*Asaphus? Vulcani*, n. s. Pl. 25. f. 5.

Head *plain, the central division being cuneiform at the front, and truncated at the anterior margin.* Central lobe *of caudal portion contracted in the middle.*

Loc. This specimen, with others too imperfect to describe, was found coiled up in the volcanic grit on the western flank of the *Corndon Mountain* above alluded to, in a ravine east of Middleton. I have, therefore, so named the fossil, that its discovery may be connected with the supposed origin of the rock in which it was imbedded. (See Chapter 22, p. 270.) The same species is found in the Caradoc formation near Wistanstow, associated with *Asaphus Powisii.*

Ogygia, Brongniart.

Gen. Char.—Corps *très déprimé, en ellipse allongée, non contractile en sphère.* Bouclier

*bordé; un sillon peu profond, longitudinal, partant de son extrémité antérieure.* Point d'autres tubercules que les oculiformes. Protubérances oculiformes, *peu saillantes, non reticulées, angles postérieurs du* bouclier, *prolongés* en pointes. Lobes longitudinaux *peu saillans. Huit articulations* à l'abdomen.

*Ogygia Murchisonicæ* (n. s.), Pl. 25. f. 3 *a* and *b*.

In establishing the genus *Ogygia,* M. Brongniart remarks that although it has a very different aspect from that of most trilobites, it is not always easily separable from other genera by neatly defined distinctions.

The best marked character, perhaps, is that of *the elongated oval form with nearly balanced extremities, and the prolongation of the buckler on each side, into a slender spike quite separated from the body.* This last-mentioned distinction of the French author is, however, not peculiar to the *Ogygia,* being, if possible, more strongly marked in the *Trinucleus.* The deep longitudinal furrow on the corslet of the buckler, may, however, be considered a generic distinction, and is quite apparent in our specimens. In the general outline and in the shape of the buckler, the Silurian species resembles the *O. Guettardi,* (Brongn.), but differs from it in several respects, particularly in having no appearance of costal divisions in the post abdomen.

Loc. The specimens figured were found by Mrs. Murchison, in a *black schistose rock at Mount Pleasant, near Caermarthen.* These beds lie very low in the Silurian System. Are they of the same age as the black slate of Angers in France, where trilobites of this form have been long known?

AGNOSTUS, Brongniart. BATTUS, Dalman.

Gen. Char.—"Corps *ellipsoide, hémicylindrique.* Bouclier et flancs *bordés, à bords un peu relevés.* Lobe moyen *ne présentant que deux divisions transversales d'une seule pièce chacune. Deux tubercules glanduleux à la partie antérieure du corps.*" Brongniart.

*Agnostus pisiformis?* Brongn., Pl. 25. f. 4 *a* and *b*.

Unable to throw any light on the history of these curious bodies, which some naturalists conceived to be crustaceans in an incipient condition[1]; I merely figure this species on the same plate as the *Asaphus Buchii,* to show that its *geological* position in the British Isles is low in the Silurian System. In Norway, the *Agnosti* apparently occur in millions, but in our rocks they are much less frequent.

Loc. *Near Builth.*

Fig. 7. Impressions of crinoidal plates of stems? in the Llandeilo flags. If these are doubtful, I may add that perfect crinoidal plates occur in the Llandeilo limestone at Clog-y-frain, near St. Clears. See Pl. 18. f. 5.

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*Postscript.*—I received the work of Pander, alluded to p. 658., at too late a period to enable me to profit much by his views concerning the original structure of the Trilobite, or the adaptations of the tegumentary skeleton of the animal to its habits, into the consideration of which he enters

[1] The notion of the *Agnostus* being a young trilobite, can have no real foundation; for, as Dalman remarks, we see the most perfect forms of certain species of trilobites, and usually of great size, not larger than peas. Eichwald has conjectured the *Agnosti* to be eggs of *Orthoceras.* According to Klöden they are related to the genus *Limulus.*

at length. He certainly throws some new light upon the nature of these creatures, by exposing the interior or under surface, particularly that of their heads, in which he points out several divisions, and considers them to be thoracic plates and jaws. The central portion, or that which was formerly described by Mr. C. Stokes from a North American specimen, Geol. Trans., vol. i. p. 208. Pl. 27. f. 1*b*., he conceives to have been connected with the head by cartilage only, and to have served as a *thoracic plate to protect the stomach,* the form of which varies in the different genera of trilobites found in Russia[1].

It is remarkable that English collectors should not yet have met with specimens in which this *plate* is discoverable, though it has been observed in Russian and American trilobites. I feel confident, however, that even with the specimens which we possess, a good naturalist may develope much of the organization of these crustaceans, by patient inquiry, and by clearing away with delicacy of hand the matrix of rock which so often obscures their under surface. The specimens Pl. 7 *bis,* f. 3 *b*. and Pl. 14. f. 3 *b*., partially illustrate my meaning; and even while these pages are going through the press, I see enough in my own cabinet to make me regret that I have not had leisure to attend more assiduously to this part of the structure of Trilobites, by a study of which we can alone hope to gain a complete acquaintance with the habits and structure of these animals, as previously suggested by Audouin and Goldfuss. (Ann. des. Sciences Nat. vol. xv. p. 83.)

On referring this subject to my friend Mr. W. MacLeay, whose knowledge of invertebrated animals is so profound, he assures me, that this plate on the underside of the head, above alluded to (Stokes, Geol. Trans. vol. ii. Pl. 27. f. 1 *b*.; Goldfuss, Ann. Scienc. Nat. tom. xv. Pl. 2. f. 8.; Pander, Beitr. Tab. 4.; Buckland, Bridgw. Treat. Pl. 45. f. 12 *f*.), must be considered the *labrum* or upper lip. The trilobite is thus brought into close analogy with certain Entomostraca, such as the *Apus cancriformis,* Latr. The reader who compares the figure of the under side of that animal (Savigny, Animaux sans Vertèbres, 2 mém. Pl. 7.) will observe a similar "labrum" and many other striking analogies with our fossils, particularly in the lateral, inflected terminations of the shelly segments of the body (*geologicè* ribs), a distinctly trilobed "pygidium" or caudal portion, and a prolonged tail; while the feet being foliaceous and the abdomen merely covered by membrane, could scarcely be expected (at least very rarely) to leave traces of their existence in a fossil state.

On the other hand, if viewed on its upper side or back (as is the case in nearly all our specimens), trilobites are more analogous to certain *Isopoda,* such as the *Cymothoadæ*[2], particularly in the eyes and buckler; and thus it is that our fossils appear, as before said, to constitute the link between two orders of existing crustaceans.

The annexed observations on the place which trilobites hold in nature have been contributed by my friend Mr. W. MacLeay in illustration of this work, while the preceding pages were passing through the press.

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[1] These genera, according to Pander, are *Calymene, Asaphus, Illænus, Amphion* and *Zethus,* the two last-mentioned being added by himself to those previously described. It would appear that another Russian author (Stschegloff) described trilobites at as early a period as Dalman, and also subdivided the genus *Asaphus,* Brongn.; calling the *Illænus* (Dalm.), *Deucalion.*

[2] Parkinson seems to have been the first to suspect an affinity between Trilobites and the genus *Cymothoa.* See Organic Remains, Oct. Ed. p. 266.

*Observations on Trilobites, founded on a comparison of their structure with that of living Crustacea. By* W. S. MacLeay, M.A. F.L.S. &c.

Trilobites were originally considered by Klein and others to be a particular kind of molluscous shell with three lobes. This supposition, however, was afterwards abandoned as untenable, and remained so until Latreille in the 7th volume of the *Annales du Muséum* revived it and referred the trilobitic fossils to the genus *Chiton* among the Mollusca. Latreille founded his argument on the presumed absence of feet, and on the lateral edges of the body in several species having been sub-coriaceous. It is evident, nevertheless, that these early inhabitants of the sea could not have belonged to the sub-kingdom *Mollusca,* since they possessed compound sessile eyes and a distinct labrum. They must, therefore, be assigned to the sub-kingdom *Annulosa,* in which we may find many articulated animals which have compound eyes and a labrum very similar in structure to those of Trilobites. Having a hard, shelly, apterous tergum and inconspicuous feet, the Trilobites must have either belonged to the Order *Chilognatha* among the *Ametabola,* or to the Class of *Crustacea.* But all the *Chilognatha* are terrestrial animals, and the obvious geological fact is, that Trilobites resided in the sea. We must clearly therefore exclude them from the *Chilognatha* and place them among the *Crustacea,* in which class it becomes now necessary to determine their exact place.

The Class of *Crustacea,* so remarkable above all other animals for the great variation of their feet, both in number and form, is divisible into two groups; those which have the eyes sessile or the *Edriophthalma* of Leach, and those which have their eyes supported on moveable peduncles or the *Podophthalma* of Leach. To the *Edriophthalma* the Trilobites clearly belong, and the question is now reduced to determine merely whether they belong to the *Amphipoda* or those existing *Crustacea* which do not undergo metamorphosis in their larva state, (among which I include not only the *Amphipoda* of Latreille, but also his *Lœmodipoda* and *Isopoda,*) or whether they belong to the *Entomostraca* or those existing *Edriophthalma* which do undergo a change of form in their larva state. I conceive that the Trilobites will be found to differ in so many respects from both the *Amphipoda* and *Entomostraca,* that according to the present state of our knowledge, we must allow them to form a distinct order, intermediate between the tribe *Isopoda* on the one side, and the tribe *Aspidophora* on the other.

Those circumstances which generally are reckoned most anomalous in the Trilobites are not in reality so very extraordinary, since they may be detected in many *Crustacea* now existing. Thus the trilobed form of the body occurs in *Serolis* and *Bopyrus.* The membranaceous or rather coriaceous margin of the body, assumed by Latreille and others to exist in Trilobites, is to be found in the female *Cymothoæ.* In these last animals also, as well as in the female *Bopyrus,* we observe the eyes to disappear as in many Trilobites. The compound eyes of *Calymene* are situated on the back of the head but wide apart, and are composed of large facets. The same structure may be seen in the male of *Cymothoa trigonocephala,* and many other *Cymothoadæ.* The absence of antennæ and the rudimentary state of the feet, both occur in *Bopyrus,* the well-known parasite of prawns. In *Spheroma* we have not only the onisciform body of *Calymene,* but also its property of rolling itself up into a ball. In *Spheroma* also we find the large convex semicircular anal segment of *Bumastus.* I think, therefore, that we can have no hesitation now in allowing the immediate affinity of the Trilobites to Isopod *Amphipoda,* and more particularly to the *Cymothoadæ* and that parasitical group which is called *Epicarides* by Latreille. Indeed, if the Trilobites are once demonstrated to have possessed articulated feet, it will be difficult to remove a male *Bopyrus* from the group. Here

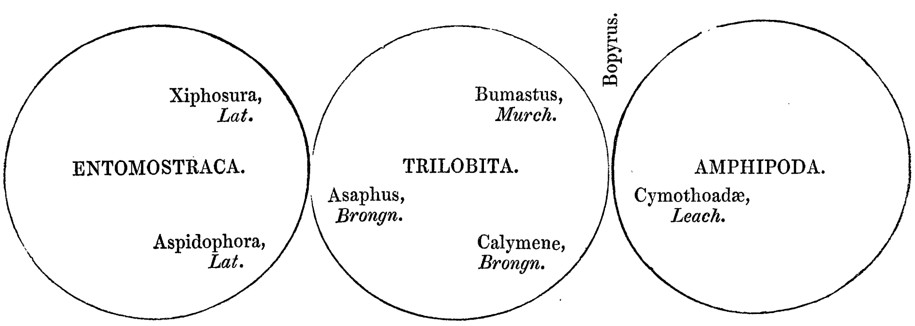
the two eyes are placed on the back of the head wide apart. Here also there are no antennæ, no posterior lateral abdominal appendages, and besides no very distinct articulation to the sternum. If the *Bumastus* of Murchison had a body of thirteen equal segments with short crustaceous feet it would be a male *Bopyrus*, so close is the affinity! The differences between a male and female *Bopyrus*, such for instance as the presence of eyes in the former and the want of them in the latter, may also induce us to fancy that similar differences may have possibly occurred between certain male and female *Trilobita*, which from their *primâ facie* difference of form are now placed in distinct genera, although they may have truly belonged to one and the same species. *Serolis* has been generally considered to come near to *Paradoxides*; but as the former has got four well-developed antennæ with crustaceous feet, and the latter none, I am inclined to believe the relation between them to be one of analogy rather than of immediate affinity.—Let us now turn to the *Entomostraca*.

Dr. Buckland, following other authors, has compared the Trilobites with the genera *Limulus* and *Branchipus*. With the latter genus, however, they obviously have no immediate affinity; although it may be well, by reference to *Branchipus*, to show that *Crustacea* can and actually do exist, with soft membranaceous feet, such as Audouin and Brongniart suspected, and Goldfuss has more lately asserted, to have been the feet of Trilobites. When, nevertheless, I take into consideration the perfect manner in which the soft body of an animal referred to me by Mr. Murchison, and by that gentleman called *Nereites Cambrensis*, has left its impression in a slaty rock, I confess I find it difficult to understand how the vestiges of legs in a Trilobite (if such legs ever really existed) should not be more evident than Goldfuss has represented them in his plates. In short, I consider the question of feet to remain still unsettled. At the same time I ought to remark, that if the Trilobites were *Crustacea*, between *Apus* and *Bopyrus*, a fact I conceive capable of demonstration, they must have been in possession of subabdominal, laminar, oviferous, appendages. Now, no traces of such appendages remain, consequently we can easily understand how feet of a similar membranaceous consistency may have disappeared in like manner. I may here observe, that Brongniart is certainly wrong in imagining that the *Ogygia Guettardi* had oval oviferous bags appendant to the abdomen like *Cyclops*, for what he considers to be such organs are more probably the membranaceous margin of the abdomen, and, besides, *Ogygia* has no immediate affinity to *Cyclops*. With reference to *Limulus*, its crustaceous, semilunar cephalothorax bears considerable resemblance to that of certain Trilobites, such as the genera *Ogygia*, *Asaphus*, *Paradoxides*, &c. In *Limulus*, we find reniform, compound eyes placed widely apart on the back of the head, and consisting of peculiar facets. We find, also, an indistinct trilobed structure of the superior abdominal shield. But then this is composed of a number of confluent segments, so as to appear of one piece; and, besides the two ocelli, the large crustaceous feet and cheliform antennæ throw *Limulus* far away from the Trilobites. We must, therefore, compare them with *Apus* and other *Aspidophora*; animals which, in my opinion, of all the Entomostraca, appear to come nearest to the *Trilobita*. Here we have a large clypeiform shell, rounded in front, and posteriorly emarginate, which forms a cephalothorax, on the back of which are situated three eyes. Of these, the two largest are lunated, and obviously correspond to the eyes of *Trilobita*, although they are placed proportionally much nearer each other. It is true they are simple, but so appear to have been the eyes of *Bumastus*[1] (see Pl. 7 *bis*, f. 3 *c*.). The abdomen, divided into many distinct seg-

[1] The distinction between smooth eyes and granulose eyes does not seem to be of much importance in these animals; for among the existing family of *Cymothoadæ* we not only see the males of some species with eyes

ments, the foliaceous feet, the structure of the front of the cephalothorax, the two rudimentary antennæ, the large labrum and projecting mandibles, all show the affinity of *Apus* to the Trilobites, more particularly to *Asaphus platycephalus,* in a specimen of which from Lake Huron, Mr. C. Stokes has discovered a subquadrate labrum, which only differs from that of *Apus* in being anteriorly deeply emarginate, while the latter is truncated. Dr. Buckland has compared this organ to that of crabs, but decapod *Crustacea* possess a very different structure, and the thing most like this labrum is to be found among the *Xiphosura,* or, still better, among the *Aspidophora* of Latreille, of which group this naturalist's genus, *Prosopistoma,* ought more particularly to be compared with Trilobites. I am not aware, however, that any Trilobite has yet occurred with vestiges of ocelli.

Still there are characters which, in my opinion, distinguish Trilobites from almost all other *Crustacea*; and among these characters I would particularly mention the absence of all lateral, posterior, abdominal appendages. Excepting *Bopyrus*[1] and certain *Læmodipoda,* all the *Amphipoda* possess these anal appendages, which are generally styliform, articulated, and in number two. The *Læmodipoda,* however, want these appendages, because the whole abdomen in them has become evanescent, a case totally different from that of Trilobites, which, like *Bopyrus,* have a well-developed abdomen consisting of many segments. I therefore consider this deficiency of anal appendages to a well-developed abdomen, when joined with the evanescent feet, and the total absence of antennæ, to be characters separating the *Trilobita* from all *Crustacea* except *Bopyrus.* The affinities of the group may be roughly expressed by the following diagram.




If we allow any accuracy to belong to the foregoing remarks on the affinities of Trilobites, it will follow that the class of *Crustacea* may for the present be distributed into orders, thus; viz.:

| Normal Group. | Orders. | |
|---|---|---|
| Podophthalma, Leach. Animals having their eyes supported on moveable peduncles. | Decapoda, Lat. | Antenniferous region of head confluent with the thorax. |
| | Stomatopoda, Lat. | Antenniferous region of head distinct from the thorax. |

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and the females without them, but we observe neighbouring genera, such as *Eurydice* and *Nelocira,* the one with granulose eyes like a *Calymene,* and the other with smooth eyes like a *Bumastus.*

[1] *Bopyrus* may possibly belong to the *Trilobita,* but I confess I do not see how *Agnostus* can. Nor do I believe that the latter fossil has any connexion with the *Annulosa* at all.

| Aberrant Group. | Orders. | |
|---|---|---|
| | Amphipoda, Lat. | Head distinct with four antennæ. Feet thick and crustaceous. Animals not undergoing metamorphosis. |
| Edriophthalma, Leach. Animals having their eyes sessile. | Trilobita, Brongn. | Head distinct without antennæ. Feet rudimentary, soft, and membranaceous. |
| | Entomostraca, Lat. | Head rarely, if ever, distinct from thorax, but provided with antennæ. Feet always distinct. Animals undergoing metamorphosis. |

With regard to the habits of true Trilobites, these animals have been supposed by some naturalists to be parasitical; but I conceive this hypothesis not to be very tenable, since almost all existing articulated parasites that adhere externally to other animals have strong feet, hooked at the end for that purpose. Now, the Trilobites certainly had no such strong crustaceous hooks to their feet, or these hooks would have long since been detected. The close affinity of Trilobites to *Bopyrus* does not prove a parasitical mode of life, for *Sphæroma* and other *Cymothoadæ* which, like Trilobites, have the power of coiling themselves up into a ball, are not parasitical, although so close in affinity to the parasitical genus *Cymothoa*. Nay, it has been said that the *Cymothoadæ* and *Epicarides* do not draw their nourishment directly from the animals to which they adhere; but, on the contrary, live entirely on the animalculæ brought to them in the water by the play of the branchiæ, near which they always take their post. Still the close connexion of Trilobites with *Bopyrus*, and their feet almost null, if not entirely so, induce me to think that these animals must have been to a certain degree sedentary. The flat under surface of their bodies, and the lateral coriaceous margin of several species, which is so analogous to that of *Chiton*, make it probable that they adhered with a soft articulated underside either to rocks or fuci. They appear to have been among *Crustacea* what the *Vermes* or white-blooded worms are among *Ametabola*,—often without eyes, and always without antennæ or distinct feet. If they had feet, as Audouin and Goldfuss imagine, and, as indeed is most probable, they must have been so small, so membranaceous, so soft, and so rudimentary, as almost to be useless to the animals for locomotion. The mouth, so analogous to that of *Apus*, makes us imagine that the Trilobites were carnivorous; and they may possibly have fed on *Acrita*, *Annelida*, or naked *Mollusca*. That they had to search for their food, and that they possessed some small power of locomotion, is to be inferred from their highly organized eyes; for no truly sessile animal is provided with sight. The *Balanus*, when it becomes sedentary, loses its eyes, as does also, in like case, the female *Coccus*. I imagine, therefore, that although the Trilobites were to a certain degree sedentary, more particularly the blind ones, they must have had some power of crawling over a flat surface; but whether they moved by rudimentary, soft, membranaceous feet, or whether it was by means of the undulation of setigerous segments, like the earthworm, or by wrinkling the under surface of the abdomen like a *Chiton*, are questions yet to be determined. One thing, moreover, is in my opinion clear, from their longitudinally trilobed form and lateral coriaceous margin, namely, that they had the power of adhering to a flat surface like a *Chiton*, *Bopyrus*, or *Coccus*. While thus sedentary, the hard, although thin, dorsal shell probably saved them in some degree from the attacks of fishes, just as that of *Chiton* protects such *Mollusca* from all fishes except the *Scaridæ*. The Trilobites probably (like *Ostreæ*, *Chitones*, *Cocci*, and other sedentary animals), adhered in masses one upon the other, and thus formed those conglomerations of individuals which are so remarkable in certain rocks.

# CHAPTER XLVIII.

## ENCRINITES AND ZOOPHYTES OF THE SILURIAN SYSTEM.

*Crinoidea*, Pl. 17 and 18. *Polyparia*, Pl. 15., 15 *bis.*, 16. and 16 *bis*. *Other Zoophytes and Nondescripts*, Pl. 26.—*Annelida of the Upper Cambrian Rocks*, Pl. 27.

THE examination of the Crinoidea and Zoophytes affords the same result as the previous inquiry into the characters of the higher grades of animals, and equally demonstrates the distinctness of the zoological types of the Silurian System.

In this chapter I have been assisted by Professor Phillips, Mr. König, M. Milne Edwards, Mr. W. S. MacLeay, and Dr. Beck; but the chief labour has devolved on Mr. Lonsdale, whose description of the corals is the condensed result of a long and critical analysis[1].

*Crinoidea.*—The continued application of a good naturalist is required to prepare a monograph of these curious tenants of the deep. Although they occur in nearly all the sedimentary deposits, ranging from the youngest to the oldest, one English work only, that of Miller, is exclusively devoted to their consideration. Availing himself of all the specimens which were accessible at the period when he wrote (1821), Miller established several new genera and species, and classed them according to their anatomical structure. As, however, the older rocks of which I treat were then little known, his list of their crinoidal contents is necessarily meagre, three species only of that age being described by him.

The subject has been since much extended in England, by the labours of Mr. Gilbertson and the writings of Professor Phillips, who gives a perspicuous account, and excellent figures of forty species of Crinoidea of the Carboniferous Limestone, seven of which only are figured in Miller's work.

My object being restricted to the illustration of the older rocks, I need not here advert to those works of foreigners and our countrymen, in which the species of Crinoidea peculiar to the younger formations are described, though I may be permitted to refer

[1] To illustrate the Silurian Rocks I presented a series of their fossils to the Geological Society, and my friend Mr. Lonsdale undertook the arduous task of comparing all the corals with their congeners in the Carboniferous Limestone of our own country, and with those of the transition rocks of the continent. I cannot too gratefully acknowledge my obligations to him for his unwearied exertions and their important results. (See p. 675 *et seq.*)

my readers to Goldfuss's beautiful work, in which they will find a detailed account of many Crinoidea of various epochs, some of which doubtless belong to the period of which we treat.

For my own part, I claim the merit of collecting good specimens, of registering them faithfully and then presenting good portraits of them; so that a mere comparison of their forms with those of the same class in the Carboniferous System, may suffice to show their distinctness. Yet, after all, as it is of the utmost importance in the establishment of an independent system of deposits, that we should appeal to authors conversant with each branch of fossils; the following account, contributed by Professor Phillips, must be perused with great interest.

In the meantime I may state, that Crinoidea are more abundant in the Wenlock formation than any other member of the Silurian System; by far the greater number of the forms described having been found in the limestone of that age near Dudley; but they also exist in other formations of the system, and are discernible from the uppermost to the lowest strata, and even in the Upper Cambrian Rocks, though usually in fragments.

"In assigning names to the following fourteen species of Crinoidea," says Professor Phillips, "no additions have been made to the genera previously described, except when a contrary course would have introduced obscurity, if not error. Whenever it has been found possible, by technical characters or general analogy of structure, satisfactorily or even probably to include species in Miller's genera, this has been done; the new genera proposed must of course be subject to correction by future researches, but the employment of them may serve to give distinctness to our conceptions of the structure of these singular fossils, and prepare the way to a more perfect classification.

CYATHOCRINITES (Miller).

*Cyathocrinites tuberculatus,* Miller. (*Crinoidea,* p. 88.) Pl. 18. f. 7.

Miller's figure is not very satisfactory as to the fingers, which in this specimen are admirable. The sutures are beautifully crenulated. The divisions of the pelvis are not traceable.

*Cyathocrinites tuberculatus, jun., ut supra.* Pl. 18. f. 6.

The pelvis in this younger specimen is not *clearly* divided, but has rather the aspect of a supra-columnar joint. The narrow rings near the pelvis, and the nodular surface of the lower part of the column are interesting points of structure.

*Cyathocrinites goniodactylus,* n. s. Phil. Pl. 17. f. 1.

Pelvic plates tuberculated; costals and scapulæ strongly ridged; arms and fingers dichotomous, externally and laterally angulated, smooth; last divisions of the fingers about 160?

Column not much larger than the fingers, bearing round branches near the base; columnar joints numerous, prominent in their round, sometimes muricated edges.

The cuneiform joint at the base of the arms rests immediately on the scapula.

*Cyathocrinites capillaris,* Phil. Pl. 17. f. 2.

Pelvic, costal and scapular plates ridged; arms and fingers dichotomous, the last divisions very long and capillary, angulated on the sides, round externally, smooth.

Column formed of many thin alternately prominent joints. The cuneiform joint at the

base of the arms is separated from the scapula by one curved joint, as in *Cyathocrinites quinquangularis,* and *C. planus* of Miller.

It appears to me that, hereafter, these three species will not be ranked in the same genus with *Cyathocrinites rugosus* of Miller.

*Cyathocrinites pyriformis,* n. s. Phil. Pl. 17. f. 6.

Its analogy to *C. tuberculatus* is considerable; but in Miller's technical arrangement it ought probably to constitute a new genus. The great width, general equality and lateral union of the plates, till the arm divisions amount to twenty, constitute easy characters. The surface is marked with a faint irregular ornament not unlike *Cyath. tuberculatus.* The upper columnar joints are very thin.

*Cyathocrinites rugosus,* Miller, p. 89. Pl. 18. f. 1.

MARSUPIOCRINITES (Phil.).

*Marsupiocrinites cœlatus,* Phil. Pl. 18. f. 3.[1]

Pelvic plates unknown, (probably five); scapulo-costals five, wide, hexagonal, each excavated on the upper edge to receive a series of small wrinkled plates, finally terminating in four longitudinally sutured fingers. The bases of the arms are separated by five interscapular plates. The whole surface is crenulato-striate; the striæ assuming a radiated form on the scapular and interscapular plates.

The column (seen in part) appears to have been pentagonal. The twenty fingers composed of two rows of joints (whence the apparent longitudinal suture) had *perhaps* no lateral tentacula?

HYPANTHOCRINITES (Phil.).

*Hypanthocrinites decorus,* Phil. Pl. 17. f. 3.[2]

In this new genus the lowest plates clearly seen appear to correspond to the first costals of the genus *Actinocrinites*; the pelvic plates were probably small.

First costals (F) five, tumid, hexagonal, equal and similar, supporting five second costals (F′), and five truncato-cuneiform scapulæ (H). On the two lateral superior edges of the scapulæ rest two pentagonal arm-joints, each bearing a cuneiform hand-joint, which supports two longitudinally sutured fingers. The summit of the scapula bears a conical plate which divides the arms and fingers of each pair.

Between the five radiating costal rows are five large tumid diagonal intercostal plates (G). On these rest in part the arm-joints, and between them *two* other approximate plates somewhat conical in form, which divide the pairs of arms and fingers, and unite with long ribs which terminate near the mouth in large tubercular plates. Similar ribs are attached to the *single* conical plates which surmount each scapula. Thus the proboscis (probably contractile) which rises above the short plumose fingers, is surrounded with several rows of tubercles, the lower one being formed of ten.

The five large intercostals surrounding by their ten bordering plates (3*a*.), ornament the basis of this encrinite with five floriform disks of great regularity and beauty. The large

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1 Believed to be a new genus, with analogies to *Rhodocrinites* of Miller, and *Actinocrinites tesseracondactylus* of Goldfuss. The name is taken from *μάρσυπος,* a purse or bag.

2 The name of this new genus is taken from the floriform aspect of the basal portion of the body, (*ὑπὸ,* under; *ἄνθος,* a flower.)

specimen figured, is in this respect not quite so perfect as another from which the outline (fig. 3 *a*.) is taken.

The column was probably short; its joints are prominent in the middle and thinnest near the body.

The arrangement of the lower plates in *Eucalyptocrinites* of Goldfuss, (Petrif., Pl. 64. f. 7.) is so very similar to that above noticed, that it is difficult to suppose the genera so entirely distinct as would be the case if *Eucalyptocrinites* be really, as Goldfuss supposes, destitute of a column. The upper part of the body of *Eucalyptocrinites* is not figured by Goldfuss, who ranks as pelvic, the plates corresponding to what are here compared to the first costals of *Actinocrinus*[1].

Actinocrinites, Miller.

Div. 1. Fingers longitudinally sutured, or composed of two rows of plates.

*Actinocrinites moniliformis*, Miller, p. 115. Pl. 18. f. 4.?

The pelvic plates are not very clearly seen in these specimens: the first and second costals and the scapula are, as represented in the drawing, unusually elongated and nearly of equal size; two broad plates (arms) attach themselves to each upper lateral edge of the scapula; the upper of these, similar in form to the scapula, supports externally one finger and internally a hand of two broad plates, which again throws off one and finally divides into two other fingers.

Thus there are forty very long and equal fingers; the manner of their ramification may be seen on the plate; each finger is formed of two rows of very numerous joints, and furnished with very expanded lateral tentacula.

The costal, intercostal, brachial, and interbrachial plates are more nearly equal in size than in any other species yet described; a broad rounded ridge traverses the costals to the base of the scapula, and, there bifurcating, runs along the arm and hand plates.

The column (which was the only part completely known to Miller) consists of joints which project in the middle, and at a distance from the body appear like beads; near the body they are thinner and alternately less and more prominent. This form of column is not sufficiently peculiar to furnish specific characters. Mr. Miller himself is in error when he speaks of this species as belonging also to the Mountain Limestone, and Goldfuss has unfortunately referred to this species as a synonym of his *Cyathocrinus pinnatus*, from which in all that regards the body and fingers it is perfectly distinct.

*Actinocrinites*, Div. 2. Fingers composed of one row of joints.

*Actinocrinites simplex*, Phil. Pl. 18. f. 8.

The pelvic, costal, and other plates of the body agree with Miller's technical formula of *Actinocrinites*; otherwise the ten fingers, externally round, with wide plumose lateral tentacula, would have led me to doubt the propriety of including it in the genus. The surface is

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[1] Several specimens of this very remarkable species have recently been found in the Dudley Limestone, the finest of which, Pl. 17. f. 3., was lent to me by Mr. Cartwright of Dudley. Another specimen is the property of Mr. H. W. Inwood. When first discovered, the fossil seemed to convey the impression of two Encrinites clasped together, but Mr. J. Sowerby at once pointed out those distinctive characters which Professor Phillips has since had the kindness to describe. I must state, in justice to Mr. Sowerby, that without his discrimination of the different forms of Crinoidea, which he had selected and drawn with much fidelity and spirit, before they were examined by Professor Phillips, this portion of my work would have been much less perfect.—R. I. M.

smooth. The general resemblance of the fingers to those of *Cyathocrinus pinnatus* of Goldfuss is so great, that, were it not for the total absence of all trace of the *external finger without tentacula* which Goldfuss speaks of, I should have ranked them together.

The generic affinities of the remaining three species cannot be determined, because no part of the pelvis is seen in either of them. They are placed provisionally with *Actinocrinites*.

*Actinocrinites? arthriticus* (*nov. spec.*), Phil. Pl. 17. f. 8.

The anterior and external edges of the joints of all the (50?) fingers are boldly tuberculate. Of short lateral tentacula there is a trace at *b*. The column was muricated.

*Actinocrinites? expansus* (*nov. spec.*), Phil. Pl. 17. f. 9.

The arrangement of the characteristic plates of the body is unfortunately unknown. The fingers ultimately amount to about 80, being unequally produced and of unequal diameter. Their lateral faces of contact are flattened. The plated integument turns into the mouth after the divisions of the arm amount to 20.

*Actinocrinites? retiarius*, Phil. Pl. 17. f. 7.

This is named provisionally. Its twenty plumose fingers appear to characterize it, and there is no longitudinal suture in them, which easily distinguishes it from *A. icosidactylus*.

Dimerocrinites, Phil.

The two following species appear to me really different, generically, from *Actinocrinites*, both by the character of the intercostal plates and the *exact bifurcation of the hands and arms*. Though unable, at present, to characterize them completely, I propose the subgeneric name of *Dimerocrinites* (διμερὴς, bipartite), and have little doubt they will be eventually separated from *Actinocrinites*.

*Dimerocrinites decadactylus*, Phil. Pl. 17. f. 4.

Intercostal plates remarkably large (as in *Hypanthocrinites*), and bearing on their summits an interbrachial plate. Fingers ten, those of the same pair separated by a small plate at their base, longitudinally sutured (i. e. composed of two rows of joints) and laterally plumose. Column formed of thin joints which project in the middle.

*Dimerocrinites icosidactylus*, Phil. Pl. 17. f. 5.

The body of this must have resembled the preceding species very much. Its scapula gives origin to two arms, which again bifurcate into twenty fingers, composed of two rows of joints, furnished with lateral tentacula.

Columnar joints moniliform, and near the body thin.

Columns of Crinoidea. Pl. 18. f. 2. and f. 9.

Nothing certain being known of the other parts of the animals to which these belong, it would be premature to assign names to them[1].

The columnar joint, Pl. 18. f. 5., *may be* a part of *Rhodocrinites quinquangularis* of Miller. (N.B. From the Llandeilo Flags.)

Besides the fourteen species noticed above, Mr. Miller describes (p. 107) *Rhodocrinites verus* as occurring both in the 'Transition and Mountain Limestone.' I have not had the opportunity of examining good specimens of this Encrinite, which, (contrary to Mr. Miller's opinion, founded I believe on columnar joints) I venture to believe does not occur at all in Mountain Limestone. There are Encrinites *like it*, which I have placed in a new genus in my

[1] I would here observe, however, that although displaying little to please the naturalist, the cast f. 2. Pl. 18. is highly characteristic of the Caradoc formation.—R. I. M.

work on the Geology of Yorkshire. Among the 40 species of Crinoidea mentioned in that work from the Mountain Limestone, there is not one of the 14 here noticed from the Silurian System; and the distinction, thus evident when species are compared, would, I believe, appear still more striking if the state of knowledge on the subject were sufficiently advanced to allow of Mr. Miller's method of classification being entirely remodelled."

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*Corals*[1]. *Described by* W. LONSDALE, F.G.S.

PLATES XV, XV *bis*, XVI AND XVI *bis*[2].

AULOPORA, Goldfuss.

*Aulopora conglomerata* (Goldfuss), Pl. 15. f. 9. nat. size.

Ref. Goldfuss, Petref. p. 83. Taf. XXIX. f. 4. 1826; De Blainville, Man. d'Actinol., p. 468. 1834; Milne Edwards, 2nd edit. Lamarck, t. ii. p. 324. 1836.

Formation and locality in England. WENLOCK LIMESTONE, *Dudley*.

Foreign locality and authority. *Bensberg*, Goldfuss.

*Aulopora consimilis*, sp. n. Lons. Pl. 15. f. 7. magnified twice.

A. encrusting, tubes round, close together, radiated, bifurcated; openings circular, raised, margin thick.

This fossil is singularly like *Aulopora compressa* of Goldfuss (Petref. p. 84. Taf. XXXVIII. f. 17.) found in the Oolitic series of Germany.

Formation and locality in England. WENLOCK LIMESTONE, *Dudley*.

*Aulopora serpens* (Goldfuss), Pl. 15. f. 6. nat. size.

Syn. and Ref. *Millepora*, Fougt. Linn. Amœn. Acad. t. i. p. 209. f. 26. 1745.

*Tubipora serpens*, Gmelin. Linn. 3754.

*Milleporites repens*, Knorr. Recueil, t. ii. p. 13. t. iii. p. 157.; Sup. Pl. VI[1]. 1775.

*Catenipora axillaris*, Lamarck, Anim. sans Vert. 1 edit. t. ii. p. 207. 1816; Lamouroux, Exp. Methodiq. p. 66. 1821.

*Tubiporites serpens*, Schlotheim, Petref. p. 367. 1820.

*Tubipora axillaris*, Parkinson, Outlines, p. 70. 1822.

*Aulopora serpens*, Goldfuss, Petref. p. 82. Taf. XXIX. f. 1. 1826; De Blainville, Man. d'Actinol. p. 468. Pl. LXXXI. f. 1. 1834; Milne Edwards, 2nd edit. Lamarck, t. ii. p. 323. 1836; Hisinger, Lethæa Suecica, p. 95. Tab. XXVII. f. 1. 1837.

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[1] The following list of Silurian corals has been prepared chiefly from the collections made by Mr. Murchison, but its compiler has had the advantage of examining valuable series of specimens belonging to the Rev. T. T. Lewis of Aymestry, Mr. Benjamin Bright of Brand Lodge, Malvern, Mr. Goodhall, and Mr. Bowerbank.

The list contains 62 species, 26 of which are supposed to be new, and the remainder have been found in the Eifel, Gothland, and other parts of Europe. It by no means includes all the corals of the Silurian formation of England; for in the rich slabs of Wenlock Limestone are many undetermined fossils; and the collections, which were examined while preparing the catalogue, contained numerous specimens, belonging apparently to unnamed species, but the state of preservation did not permit their characters to be ascertained.

[2] These plates have been lithographed by Mr. Scharf, with great care and strict attention to fidelity of character.

*Alecto serpens*, Alex. Brongniart, Tableau des Terr. p. 430. 1829; Steininger, 1831, Mém. Geol. Soc. Franc. t. i. p. 341. Pl. XX. f. 9. 1834.

*Stomatopora serpens*, Bronn. Lethæa Geognostica, p. 54. Taf. V. f. 10 *a* and *b*. 1835.

Formations and localities in England. WENLOCK LIMESTONE, *Lincoln Hill, Coalbrook Dale; Winslow Mill, Lindels, Fownhope, Woolhope; Dudley*. UPPER LIMESTONE OF THE CARADOC FORMATION; *Prolimoor Well, and Norbury, Salop.*

Foreign localities and authorities. *Shores of the Baltic*, Fougt; *Bursvik, Gothland*, Hisinger; *Eifel*, Bronn, Goldfuss, Schlotheim, Steininger; *Bensberg*, Knorr, Bronn; *Arnsberg*, Bronn.

*Aulopora tubæformis* (Goldfuss), Pl. 15. f. 8. nat. size, attached to *Cystiphyllum cylindricum*.

Syn. and Ref. Goldfuss, Petref. p. 83. Taf. XXIX. f. 2. 1826.

*Alecto tubæformis*, Steininger 1831, Mém. Soc. Geol. France, t. i. p. 341. 1834.

Formation and locality in England. WENLOCK LIMESTONE, *Benthall Edge*.

Foreign locality. *Eifel*, Goldfuss, Steininger.

ESCHARINA, Milne Edwards.

*Escharina? angularis*, sp. n. Lons. Pl. 15. f. 10. nat. size, 10 *a* magnified.

E. encrusting? disk-shaped, raised around the edge: cells distinct, angular, close together, radiating from a centre, parallel to the surface of the disk; openings of the cells not perfect.

Formation and locality. WENLOCK LIMESTONE, *Dudley*.

PTILODICTYA, g. n. Lons., *Πτίλον, pluma*; *δίκτυον, rete*.

Generic Characters.—Thin, elongated expansions, having on each surface small quadrangular cells not convex, which penetrate the coral obliquely, and are arranged with respect to the surface, along the middle of the specimen, parallel to the elongated direction of the coral, but on the sides obliquely from it. Surface, a very thin calcareous crust traversed by slightly raised ridges, marking the boundaries of the cells; towards the margin the crust thickens, the indications of the cells are less distinct, and at the edge are invisible; but cells are traceable close to the margin where the crust has been removed; opening of the cells small, transversely oval? no indication of a central partition parallel to the surface.

This fossil is considered by Goldfuss to be a *Flustra*, but it is placed by Milne Edwards among the doubtful species of that genus (2nd edit. Lamarck, t. ii. p. 229.). It differs essentially from *Flustra* in the thickening of the external crust, most probably not preserved in Goldfuss's specimens. From *Eschara* it differs in not having a central partition, and in the surface of the cells not being convex, but depressed as in *Flustra*. I have, therefore, ventured to propose the above name taken from the *feather-like* arrangement of the middle and lateral cells, and their *net-like* union.

*Ptilodictya lanceolata*, Lons. Pl. 15. f. 11, 11 *a* to 11 *c*.—11 nat. size, 11 *a* portion of the same magnified twice, 11 *b* a young specimen, 11 *c* the same magnified 3 times.

P. Expansion long, narrow, flat, slightly curved longitudinally, and thin gradually diminishing to a fine edge; middle cells narrow, small and about 10 rows; lateral cells larger and arranged in rows slightly arched from the middle to the edge, the cells themselves placed obliquely both with respect to the middle of the coral and the arch.

Syn. and Ref. *Flustra lanceolata*, Goldfuss, Petref. p. 104. Taf. 37. f. 2. 1826, 1833; Hisinger, Lethæa Suecica, p. 104. Tab. XXIX. f. 10. 1837.

The figures 11 and 11 *a*. Pl. 15. do not exactly agree with those in the above references, but the differences are probably due to the state of preservation not being the same.

Formation and locality in England. WENLOCK LIMESTONE, *Malvern Hills* (*western slopes of*).

Foreign localities and authorities. *Groningen,* Goldfuss; *Capelhamn and Hoburg in Gothland, Bursvik,* Hisinger.

Small fragments of probably young specimens of this species are occasionally found in the slabs of Wenlock Limestone; one of them is represented on Pl. 15. f. 11 *b,* 11 *c.*

GLAUCONOME, Goldfuss.

Goldfuss has described under the generic name of *Glauconome* five fossils, four of which, according to De Blainville (Man. d'Actinologie, p. 454.) and Milne Edwards (2nd Edit. Lamarck, t. ii. p. 193.), belong to the genus *Vincularia,* previously established by De France (Dict. Sc. Nat. tom. lviii. p. 214.). The fifth species, common at Dudley, possesses, however, characters essentially different from those of *Vincularia,* and even from those assigned to *Glauconome* by Goldfuss. Instead of the stem being impressed on all sides with rows of cells, it has them over only half the surface, the other half being striated longitudinally. It is probable that the position of the fossil in the matrix prevented that author from detecting the true characters of the coral. For this fossil it has been thought right to retain Goldfuss's name, but a modification in both the generic and specific characters has become necessary.

Gen. Char.—Stem stony, thin, elongated, oval, branched; cells disposed longitudinally and alternately in rows over one half the surface, the other half striated longitudinally. Nature of the covering and opening of the cells unknown.

*Glauconome disticha* (Goldfuss), Pl. 15. f. 12, 12 *a* to 12 *d.*—12, 12 *a* cellular surface nat. size, 12 *b* is 12 magnified twice, 12 *c,* 12 *d* striated surface nat. size and magnified twice.

G. Stem branched, the branches diverging nearly at right angles both from the central stem and from the lateral branches; four rows of long quadrangular cells on one side; the opposite side striated.

Ref. Goldfuss Petref. p. 217. Taf. LXIV. f. 15.

Formation and localities in England. WENLOCK LIMESTONE, *Lincoln Hill, Coalbrook Dale, Dudley.*

Foreign locality and authority. *Eifel,* Goldfuss.

HORNERA, Lamouroux.

*Hornera crassa,* sp. n. Lons. Pl. 15. f. 13, 13 *a* cellular surface nat. size and magnified thrice.

H. Branches short, *thick,* flat, dichotomosed; opening of the cells large, elevated, and irregularly disposed on one side; opposite side striated; internal structure not ascertained.

Formation and locality. WENLOCK LIMESTONE, *Dudley.*

FENESTELLA, Miller.

Professor Phillips having informed me that the late Mr. Miller of Bristol employed the word *Fenestella* to distinguish a mountain limestone coral possessing generic characters similar to those of the fossils represented Pl. 15. f. 15 to 19, I have conceived it my duty to adopt the name, though not published; and I have ventured to call one of the species *Fenestella Milleri,* as a tribute of respect to departed talent.

Gen. Char.—A stony coral, fixed at the base (f. 15, 15*.) and composed of branches which unite by growth and form a cup (f. 15 to 15 *c*). Externally the branches anastomose (f. 19.), or regularly bifurcate (f. 15, 16, 17, 18.); internally they form a net-work, the intervals being generally oval (f. 15, 18 *c*). One row of pores on each side of the branches externally, the openings being circular and projecting when perfect (f. 16 *a,* &c.). The branches, when regularly bifurcated, are connected by distant, transverse processes, in which no projecting pores are visible (f. 16 *a*). In well-preserved specimens of the base of apparently old corals, the

pores or foramina on the side of one branch have united by growth to those on the side of the adjoining branch, and constitute solid bars, either stretching transversely and simply across the intervals, or uniting obliquely three and sometimes more together.

Figs. 15, *a, b, c.* partly exhibit the changes effected by growth in this genus, the figures with an asterisk being magnified.

Figs. 15, 15*. This specimen consists of several detached branches fixed to an organic body. The pores or foramina project from the sides of the branches, but are not united. In this specimen both the external and internal structure are exposed.

Figs. 15 *a*, 15 *a**, 15 *b*, 15 *b**. The foramina in several of the rows exhibited in these figures are united, and nearly level with the surface of the branches; in others they are not quite united, or are depressed in the centre.

Figs. 15 *c*, 15 *c**. The union of the foramina in this specimen is complete throughout, and the bars are all on a level with the branches.

It is very difficult to establish species from fragments, but the four following are believed to be distinct from each other.

*Fenestella antiqua*, Lons. Pl. 15. f. 16, 16 *a* nat. size and magnified twice.

F. Branches bifurcated, rather distant, transverse processes very apparent, giving the exterior a quadrangular net-work character; foramina or pores not numerous nor close. Nature of the interior reticulation not ascertained.

Syn. and Ref. *Gorgonia antiqua?* Goldfuss, Petref. p. 99. Taf. XXXVI. f. 3 *a*. 1826.

Formation and locality in England. WENLOCK LIMESTONE, *Dudley*.

Foreign locality and authority. *Eifel*, Goldfuss.

*Fenestella Milleri*, sp. n. Lons. Pl. 15. f. 17. magnified 2½ times.

F. Outer surface, branches very thin, knife-edged, close together, regularly bifurcated: pores on the sides of the branches very small, most apparent in the upper part: transverse processes thin, rather distant, not very distinct: opposite or inner side, regular net-work.

Formation and locality. WENLOCK LIMESTONE, *Dudley*.

*Fenestella prisca*, Lons. Pl. 15. f. 18, 18 *a* to 18 *c*.—18, 18 *a* nat. size and magnified thrice, 18 *b* external surface worn, 18 *c* inner surface of the same.

F. Branches externally slender, generally near each other, bifurcated; foramina numerous and close: in the internal net-work, the intervals are oval or oblong with rounded angles, and very variable in size.

The specimen (f. 18.) is from near the base of the coral, but in other specimens, apparently from the upper part, the foramina are equally numerous. The figures 15, &c. apparently belong to this species.

Syn. and Ref. *Retepora prisca*, Goldfuss, Petref. p. 103, Taf. XXXVI. f. 19. The worn specimen from Dudley, represented in Pl. 15. f. 18 *b*., strongly resembles Goldfuss's coral.

Formation and locality in England. WENLOCK LIMESTONE, *Dudley*.

Foreign locality and authority. *Eifel*, Goldfuss.

*Fenestella reticulata*, Lons. Pl. 15. f. 19, 19 *a* nat. size and magnified 2½ times.

F. Branches irregularly anastomosed: foramina large, rather distant: reticulation of the inner surface similar to that of the external.

Syn. and Ref. *Retepora reticulata?* Hisinger, Lethæa Suecica, p. 103. Tab. XXIX. f. 8.

Formation and locality in England. WENLOCK LIMESTONE, *Dudley*.

Foreign locality and authority. *Gothland?* Hisinger.

DISCOPORA, Lamarck.

*Discopora antiqua?* (Milne Edwards), Pl. 15. f. 21, 21 *a* upper surface worn, nat. size and magnified, 21 *b* upper and under surfaces nat. size.

Syn. and Ref. *Cellepora antiqua*, Goldfuss, Petref. p. 27. Taf. IX. f. 8. 1826.

*Membranipora antiqua*, De Blainville, Man. d'Actinol., p. 447. 1834.

*Discopora antiqua*, Milne Edwards, 2nd Edit. Lamarck, t. 2. p. 253. 1836.

The opening of the cells is less regular in form and arrangement than in that given in Goldfuss's magnified figure; the indentations are also less distinct and regular. The specimens of this coral are generally much worn on the upper surface, and the opening of the cells is therefore not often visible; but where it has been preserved the upper wall is arched, as in the next species. The under surface is smooth or marked with concentric lines (f. 21 *b*.).

Formation and locality in England. WENLOCK LIMESTONE, *Dudley*.

Foreign locality and authority. *Eifel*, Goldfuss.

*Discopora squamata*, sp. n. Lons. Pl. 15. f. 23, 23 *a* nat. size and magnified.

D. Cells contiguous, more or less regularly disposed, opening not contracted, vertical, upper margin projecting, arched.

Formation and localities. WENLOCK LIMESTONE, *Dudley; Hurst Hill, Sedgley*.

*Discopora? favosa*, Lons. Pl. 15. f. 22, 22 *a* nat. size and magnified twice.

Syn. and Ref. *Cellepora favosa*, Goldfuss, Petref. p. 217. Taf. LXIV. f. 16.

This fossil presents an elevation in the centre as if composed of more than one layer of cells; but a similar specimen, when worn down vertically, consisted of a single layer.

Formation and locality in England. WENLOCK LIMESTONE, *Dudley*.

Foreign locality and authority. *Eifel*, Goldfuss.

BERENICEA, Lamouroux.

*Berenicea irregularis*, Pl. 15. f. 20, 20 *a* nat. size and magnified.

B. Opening of the cells round, distant where the surface is flat, generally near together where it is uneven; more or less regularly disposed from a centre.

Formation and locality. WENLOCK LIMESTONE, *Dudley*.

RETEPORA, Lamarck.

*Retepora infundibulum*, sp. n. Lons. Pl. 15. f. 24 nat. size.

R. *Funnel-shaped*; branches united in a thick net-work, the interstices being small and variable in shape: inner surface two vertical rows of pores.

The arrangement of the pores is similar to that in *Fenestella*, but on the inner, and not the external surface. A very small fragment only of the interior has been examined.

Formation and locality. WENLOCK LIMESTONE, *Dudley*.

ESCHARA, Pallas, Lamarck.

*Eschara? scalpellum*, sp. n. Lons. Pl. 15. f. 25, 25 *a* nat. size and magnified twice, 25 *b* section.

E. *Lancet-shaped*: cells more or less oval, nearly opposite on the two surfaces: outer rows, cells smaller and more distant than in the other rows: edge of the coral when perfect, solid, faintly striated and sharp: outer covering and opening of the cells unknown.

This coral is placed in the genus *Eschara*, on account of the apparent thickening of the surface of the outer cells; and the cells being nearly opposite on the two sides. In some specimens the thickening of surface of the outer row is so great as nearly to obliterate the opening of the cells.

Formation and locality. WENLOCK LIMESTONE, *Dudley*.

BLUMENBACHIUM, König.

*Blumenbachium globosum?* (König.), Pl. 15. f. 26, 26 *a* nat. size and magnified twice.

Ref. Icones Fossilium Sectiles. Cent. Prima, p. 3. Tab. V. f. 69.

The specimen figured in Pl. 15. differs from that represented in the Icones Fossilium Sectiles. The rays are compound, and are indistinct in number, but exceed four. The surface is not distinctly punctured, the few pores which are visible having been produced probably by the unequal action of the acid, used in preparing the slab for sale. The interstices between the stars are also unequally furrowed. It has, nevertheless, not been thought advisable to consider the specimen as belonging to a distinct species.

Formation and locality. WENLOCK LIMESTONE, *Dudley.*

GORGONIA, Linnæus.

*Gorgonia assimilis,* sp. n. Lons. Pl. 15. f. 27 nat. size, 27 *a* portion magnified to show the striæ.

G. Axis round, branched, faintly striated longitudinally: branches anastomosed: no projecting papillæ, or impressed pores.

It is impossible to determine if this fossil be a true *Gorgonia*; but from its *great resemblance* to the axis of some existing species, I have ventured to place it in that genus.

Formation and locality. WENLOCK LIMESTONE, *Dudley.*

Pl. 15. f. 28, 28 *a* represent a portion of a coral which may be a *Gorgonia.* It was found in Encrinital Shale at Alfric, Malvern.

CERIOPORA, Goldfuss.

*Ceriopora granulosa* (Goldfuss), Pl. 15. f. 29, 29 *a* nat. size and magnified.

The internal structure of this coral I have not ascertained.

Ref. Goldfuss, Petref. p. 217. Taf. LXIV. f. 13.

Formation and locality in England. WENLOCK LIMESTONE, *Dudley, Ledbury.*

Foreign locality and authority. *Eifel,* Goldfuss.

HETEROPORA, De Blainville, not Ehrenberg.

*Heteropora crassa,* sp. n. Lons. Pl. 15. f. 14, 14 *a* nat. size and portion magnified.

H. Branched, the branches *thick,* tubes small, radiating from a centre; transverse fracture concentric layers formed of two systems of tubes, one visible to the naked eye, the other microscopic, numerous and close together.

Formation and locality in England. WENLOCK LIMESTONE, *Benthall Edge.*

The specimen is in the collection of Mr. Goodhall.

MILLEPORA, Linnæus.

*Millepora repens* (Hisinger), Pl. 15. f. 30, 30 *a* nat. size; the former is from a worn specimen.

Syn. and Ref. *Millepora,* Fougt, 1745., Linn. Amœn. Acad., t. i. p. 202. f. 15., 1749.

*Millepora repens,* Hisinger, Lethæa Suecica, p. 102. Tab. XXIX. f. 5., 1837.

In the regularity of the openings, this coral resembles the genus *Seriatopora*; but it differs from the *Seriatopora subulata,* (Lamk.), in being cellular and not solid in the centre.

Formation and localities in England. WENLOCK LIMESTONE, *Lincoln Hill, Coalbrook Dale, Benthall Edge, Dudley, Hurst Hill, Sedgley.*

Foreign localities and authorities. *Shores of the Baltic,* Fougt; *Gothland,* Hisinger.

STROMATOPORA, Goldfuss.

*Stromatopora concentrica* (Goldfuss), Pl. 15. f. 31 to 31 *d.*—31 nat. size, 31 *a* portion of the surface magnified, 31 *b* section of 31, 31 *c* part of 31 *b* magnified twice, 31 *d* small portion of a large specimen in which the very thinly laminated structure is obliterated.

Ref. Goldfuss, Petref., p. 22. Taf. VIII. f. 5., 1826; De Blainville, Man. d'Actinol., p. 413. Pl. LXX. f. 1., 1834.

Formations and localities in England. WENLOCK LIMESTONE, *Dudley; Lincoln Hill, Benthall Edge, Wenlock; Conygree Wood, Ledbury; West flank of the Malverns; Winslow Mill, Woolhope;* WENLOCK SHALE, *south end of Lower Lickey.*

A magnificent hemispherical specimen of this coral, fourteen inches in diameter, was found at Haven near Aymestry in Wenlock Limestone, by the Rev. T. T. Lewis.

Foreign locality and authority, *Eifel,* Goldfuss.

*Stromatopora nummulitisimilis,* sp. n. Lons. Pl. 15. f. 32, 32 *a* nat. size and magnified twice.

S. Small, very flattened spheroids, *similar to a nummulite* in shape, and composed of many thin concentric layers, formed around a nucleus, consisting generally of a joint of a crinoidal remain.

Formation and localities. WENLOCK LIMESTONE, *Crews' Hill near Alfrick, Worcestershire; Mathon Lodge, Malvern; and also at Lye near Aymestry*[1].

ALVEOLITES, Lamarck.

*Alveolites? fibrosa,* sp. n. Lons. Pl. 15. f. 1, 1 *a* nat. size.

A. Encrusting; layers concentric, thin, but of unequal thickness, tubes short, externally angular, internally round. No connecting foramina detected: surface of the tubes in each layer slightly concave.

It is not without hesitation that this fossil is placed in the genus *Alveolites.* The specimens first examined, presented only one layer of tubes ranging the whole thickness of the coral (f. 1 *a*), and they were believed to be a variety of *Favosites fibrosa.* (See *ante,* p. 612, *Turbo Corallii.*) The beautiful specimen in Pl. 15. f. 1, was afterwards added to the collection: and from regularity in the surface of each layer, I have been induced to remove the coral into the genus *Alveolites.* On examining several specimens of the different species of *Favosites,* so great a diversity was found in the range of the transverse divisions within the tubes, that no fracture could give the level uniformity of surface presented by the fossil here called *Alveolites fibrosa.*

Formations and localities. UPPER LUDLOW ROCK AND AYMESTRY LIMESTONE, *Larden, Churn Bank, or Palmer's Cairn near Ludlow.*

FAVOSITES, Lamarck.

*Favosites alveolaris* (De Blainville), Pl. 15 *bis.* f. 1, 1 *a,* 1 *b,* 2, 2 *a.*—1 segment of a hemispherical mass, nat. size, 1 *a* portion magnified twice, 1 *b* exhibits the internal lamellæ, 2 is from a larger variety, nat. size. The pores are well displayed upon the angles of this specimen, but near the base of one of the tubes are four pores on the surface of the plane.

The distinguishing specific character consists in the connecting foramina being on the angles of the tubes.

Syn. and Ref. *Calamopora alveolaris,* Goldfuss, Petref. p. 77. Taf. XXVI. f. 1, 1826.

*Favosites prismaticus,* Steininger, 1831, Mém. Soc. Geol. France, T. 1. p. 335, 1834.

*Favosites alveolaris,* De Blainville, Man. d'Actinol., p. 402, 1834; Goldfuss, Petref. Corrigenda, p. 245, Milne Edwards, 2nd Edit. Lamarck, t. 2. p. 320, 1836.

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[1] A mass eight inches long, seven broad and two thick, consisting almost entirely of this small coral, was found by the Rev. T. T. Lewis and myself at Crews' Hill, north of the Malvern Hills; and to the zeal of my friend in carrying this specimen when added to a well-loaded bag, the preservation of the mass entire is due. Mr. Lewis has since found the species in the Wenlock Formation near Mathon Lodge, Malvern.—R. I. M.

The size of the tubes of this species, as well as of *F. Gothlandica,* varies considerably. The difference in the development, and in the apparent position of the angular foramina, is likewise often so great, that detached portions of the same specimen might be thought specifically different. In the magnified portion (1 *a*) of f. 1, many of the variations in the character of the foramina are exhibited. Where (f. 1 *a**) the fracture has exposed the tubes with the sides in juxtaposition the foramina lock into each other, and alternate, and there are no interstices; but where (f. 1 *a***) the angle of one tube is exposed, opposite to the angle of another, the foramina unite and interstices are visible for the passage of the intermediate foramina of two other tubes. In some parts of this specimen the foramina are scarcely discernible, even with a lens; while in others they stand out in bold relief, and are perceptible to the touch.

Small globular masses, having a honey-comb surface, are common at Dudley, Wenlock and other localities, and belong either to *F. alveolaris* or *F. Gothlandica.*

Formations and localities in England. MIDDLE AND LOWER LUDLOW ROCK, *Mocktree Hill, Aymestry, Tatton Edge;* WENLOCK LIMESTONE, *Wenlock, the Purlieux, Malvern, Haven near Aymestry, Leinthall Earls near Ludlow, Hurst Hill near Sedgley, West flanks of Malvern Hills, Abberley, Little Ridge, Easthope, Winslow Mill, Fownhope, Westhope, Woolhope;* CARADOC SANDSTONE, *Powis Castle, Cefn-y-garreg, Llandovery.*

Foreign localities and authorities. *Eifel,* Goldfuss, Steininger; *Groningen,* Goldfuss.

*Favosites Gothlandica* (Lamarck), Pl. 15 *bis.* f. 3, 3 *a,* 4.—3, 3 *a* nat. size and magnified one half; 4 is a section exhibiting change in the number of the connecting foramina.

It has been deemed advisable to include in one species, *F. Gothlandica* and *F. basaltica,* as the distinction, founded upon the sides of the tubes being perforated by two rows of pores or by one row, has not been found to be satisfactory. In f. 4. both characters are exhibited in the same specimen, and other similar instances have been noticed.

Syn. and Ref. *Coralloidea oblonga pentaedra,* Woodward Nat. Hist. Foss. T. 1. p. 136, 1729.

*Corallium Gothlandicum,* Fougt. 1745, Linn. Amœn. Acad. T. 1. p. 211. f. 27, 1749.

*Astroïte demi-sphérique?* Guettard, Mém. T. 2. pp. 438, 499, Pl. XVI. f. 2. Pl. XLV. f. 1, 1770.

*Favosites Gothlandica,* Lamarck, 1st Edit. Anim. sans Vert. T. 2. p. 206, 1816; Schweigger, Beobacht. VII., 1819; De France, Dic. Sc. Nat. T. 16, p. 298, 1820; Lamouroux, Expos. Méthodiq., p. 66, 1821; Parkinson, Outlines, p. 69; Org. Rem. vol. ii. p. 69, Pl. VIII. f. 3, 7, 1822; De Blainville, Man. d'Actinol., p. 402, Pl. LXII. f. 4, 1834, *F. Gothlandica* and *F. basaltica,* Milne Edwards, 2nd Edit. Lamarck, T. 2. p. 303, 1816.

*Spongites favus,* Schlotheim. Petref. p. 369, 1820.

*Calamopora Gothlandica, C. basaltica,* Goldfuss, Petref. p. 78, Taf. 26, f. 3, 4, 1826; (*Favosites corrigenda,* p. 245, 1833) Ehrenberg 1831, Abhandl. König. Akad. Berlin, 1832, p. 346. Hisinger, Lethæa Suecica, p. 96, Tab. XXVII, f. 4, 5, 1837.

*Sarcinula angularis,* Fleming, Brit. Anim. p. 508, 1828.

*Favosites prismaticus,* Steininger, 1831, Mém. Soc. Geol. France, T. 1, p. 335, 1834.

Formations and localities in England. MIDDLE LUDLOW ROCK, *Aymestry, Tatton Edge, Downton-on-the-Rock;* LOWER LUDLOW ROCK, *Sitch Wood, Ledbury, Westwood Common, Wenlock;* WENLOCK LIMESTONE, *Wenlock, Wren's Nest, Dudley, Evenhay;* CARADOC SANDSTONE, (Upper calcareous beds) *Daniel's Wood, Tortworth.*

Foreign localities and authorities. *Gothland,* Schlotheim, Lamarck, Goldfuss, Hisinger;

*Shores of the Baltic,* Fougt.; *Nietzwitz in Lithuania* Guettard; *Osmundsberg in Dalacarlia,* Hisinger, *Groningen,* Goldfuss; *Eifel,* Goldfuss, Schlotheim; *Lake Erie and Drummond Island,* Goldfuss.

*Favosites multipora,* sp. n. Lons. Pl. 15 *bis.* f. 5, 5 *a* to 5 *c.* nat. size, 5 under surface, 5 *a* vertical section, 5 *b* detached tubes showing the pores, 5 *c* weathered upper surface.

F. discoid, under surface grooved concentrically, but marked with the lower terminations of the tubes; upper surface flat, covered with the scale-like openings of the tubes. Tubes hexagonal, composed of two narrow opposite planes, and four broad ones, variable in their proportions; position vertical or slightly curved towards the base; sides pierced by *numerous pores* irregularly disposed and not uniform in size; interior traversed by horizontal septa.

This species is distinguished by the number of the pores, which in some places give the tubes the net-work character of *Alveopora.* From that genus, however, this fossil is distinguished by the transverse horizontal septa. A specimen of the cast of the upper surface contained in the collection, bears a singular resemblance to a shagrin fish-skin, f. 5 *c.*

Formation and locality. WENLOCK LIMESTONE, *Marloes Bay.*

*Favosites fibrosa* (Goldfuss), Pl. 15 *bis.* f. 6, 6 *a* to 6 *f.*—6 vertical section nat. size, 6 *a* tubes magnified showing the transverse lamellæ, 6 *b* transverse section of a globular specimen with indications of the angular foramina, 6 *c* another in which they are very distinct, 6 *d* portion of the same magnified 3 times, 6 *e* and 6 *f* a vertical radiating specimen nat. size and magnified.

Syn. and Ref. *Millepora ramis vagis punctis sparsis?* Fougt. 1745, Amœn. Acad. T. 1. p. 201, fig. 12, 1749.

*Calamopora fibrosa,* Goldfuss, Petref. pp. 82, 215, Taf. LXIV. f. 9, 1826.

*Favosites fibrosa,* Goldfuss, Petref. Corrigenda, p. 245, 1833.

*Chaetetes?* Fischer, Oryc. de Moscou, Tab. XXXVI. 1830.

*Favosites microporus,* Steininger, 1831, Mém. Soc. Geol. France, T. 1. p. 337, 1834.

This species appears to have a great geological range in the Silurian System. It is also abundant, and the varieties incident upon growth are numerous. Some specimens are globular, others are cylindrical, and many are branched. The connecting angular foramina are occasionally well displayed, either in parts or over the whole of a specimen; but they are oftener not to be detected, and the fossil then strongly resembles the *Chaetetes* of Fischer. At Golden Grove, Old Radnor, Botville, and other localities, occurs a slender-branched coral, composed of fine angular tubes, radiating from an imaginary axis (7 nat. size, 7 *a* magnified). I have not been able to detect satisfactorily connecting foramina; but from a careful comparison of the specimens with others belonging to thick-branched varieties of *Favosites fibrosa,* in which the connecting foramina are partially exposed, no perceptible difference has been observed. In the impure limestone of Bala, a similar fossil is found. In the mountain limestone of Steeraways small fragments of a coral not distinguishable from this variety have also been noticed.

Formations and localities in England. UPPER LUDLOW, *Hanway, and Birches Common near Ludlow;* MIDDLE AND LOWER? LUDLOW ROCK, *Aymestry, Caynham Camp;* WENLOCK LIMESTONE, *Chain Bridge near Usk; Haven near Aymestry, Old Radnor;* CARADOC SANDSTONE, *Horderly and Wittingslow, Salop, Ankerdine Hill, Llandovery;* LLANDEILO FLAGS, *Rorrington near Shelve, Salop.*

Foreign localities and authorities. *Eifel,* Goldfuss, Steininger; *Bensberg,* Goldfuss; *Lexington* in *Kentucky* and *Buffalo Creek, Canada,* Goldfuss.

*Favosites spongites* (Goldfuss), Pl. 15 *bis.* f. 8, 8 *a* to 8 *e.*—8 upper surface nat. size, 8 *a* and 8 *b* ver-

tical section nat. size and magnified, 8 *c* vertical section of a cylindrical variety, 8 *d* and 8 *e* terminations of the tubes on the outer surface.

Syn. and Ref. *Alveolites suborbicularis,* Lamarck, Anim. sans Vert. 2. p. 186, 1816; De Blainville, Man. d'Actinol., p. 404, 1834; Steininger, 1831, Mém. Soc. Geol. de France, t. 1. p. 334. Pl. XX. f. 4, 1834; Milne Edwards, 2nd Edit. Lamarck, t. 2. p. 286, 1836.

*Escharites spongites,* Schlotheim, Petref. p. 345, 1820.

*Calamopora spongites,* Goldfuss, Petref. p. 80. Taf. XXVIII. f. 1, 1826. *Favosites,* Goldfuss, Corrigenda, p. 245, 1833.

This fossil is retained among the *Favosites,* because it possesses connecting lateral foramina; and because it does not consist, in the specimens which have been examined, of concentric, encrusting layers of short tubes, the essential character, according to Lamarck, of the genus *Alveolites.*

The specimen f. 8. is in the collection of Mr. Goodhall; and that represented in f. 8 *c.* is in the collection of Mr. Bowerbank. The former is from Benthall Edge, the latter from Wenlock.

The fossil figured by Goldfuss, Taf. XLIV. f. 10., and assigned to this species, is common in the slabs of limestone at Dudley. (see Pl. 15 *bis.* f. 9, 9 *a*, 9 *b*.)

Formation and localities in England. WENLOCK LIMESTONE, *Benthall Edge, Lindells, near Fownhope.*

Foreign localities and authorities. *Eifel,* Schlotheim, Steininger; *Sweden, Bensberg, Dollendorf,* Goldfuss; *Dusseldorf,* Lamarck, De Blainville; *Drummond Island,* Goldfuss.

*Favosites polymorpha* (Goldfuss), Pl. 15. f. 2 nat. size.

Syn. and Ref. *Calamopora spongites,* Goldfuss, p. 80. Taf. XXVIII. f. 2 *b*, 1826; Hisinger, Lethæa Suecica, p. 97. Tab. XXVII. f. 7.

*Favosites,* Goldfuss, Corrigenda, p. 245.

*Alveolites reticulata,* De Blainville, Man. d'Actinologie, p. 404, 1834.

Goldfuss in his description of *Calamopora* (Favosites) *spongites,* says, that it is probably a variety of *C. polymorpha* (p. 81.). It is, therefore, considered as such in this list; and by including it in that species, all the fossils having this peculiar branched form are brought together, and separated from *F. spongites,* var. *α.* (Goldfuss), which thus becomes the type of a well-defined distinct species.

Formation and localities in England. LUDLOW ROCKS, *Ludlow, Aymestry.*

Foreign locality and authority. *Bensberg,* Goldfuss.

SYRINGOPORA. Goldfuss.

*Syringopora reticulata* (Goldfuss), Pl. 15 *bis.* f. 10, 10 *a* nat. size and the termination of the tubes magnified.

Syn. and Ref. *Tubiporites subulatus?* Schlotheim, Petref. p. 368, 1820.

*Syringopora reticulata* (Goldfuss), Petref. p. 76. Taf. XXV. f. 8, 1826; De Blainville, Man. d'Actinol., p. 353, 1834 Milne; Edwards, 2nd Edit.; Lamarck, t. 2. p. 328, 1836; Hisinger, Lethæa Suecica, p. 95. Tab. XXVII. f. 2, 1837.

*Harmodites parallela.* Fischer[1], Oryc. de Moscow, T. XXXVII. f. 6, 1830. Bibliographia Palæonthologica, p. 341, 1834.

*Harmodites radians.* Bronn, Lethæa Geognostica, p. 51. Taf. V. f. 7, 1835.

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[1] Fischer's genus *Harmodites* is of anterior date to Goldfuss's genus *Syringopora*; but the latter having been adopted by naturalists, it is retained in this list.

Formation and locality in England. WENLOCK LIMESTONE, *Gleedon Hill, Wenlock.* The specimen figured is in the collection of Mr. Bowerbank, and was found at Wenlock.

Foreign localities and authorities. *Government of Moscow,* Fischer; *Olne* (Belgium), Goldfuss, Milne Edwards; *Gothland,* Hisinger; *Sweden?* Schlotheim.

Of these foreign localities, Olne is considered by Von Dechen (German trans. De la Beche's Man.) to be carboniferous limestone; but Goldfuss states that it is transition, and he constantly distinguishes between Bergkalk and Uebergangskalk. Hisinger, Bronn, and Fischer mention *S. reticulata* as found at localities where other Silurian (transition) fossils occur. Dumont also enumerates *S. ramulosa,* stated by Goldfuss to be found at Olne, among his lists of transition or Silurian fossils.

*Syringopora bifurcata,* sp. n. Lons. Pl. 15. f. 11, 11*a*, 11*b*.—11 upper surface and vertical section, 11 *a* under surface, 11 *b* tube magnified.

S. Branched, *bifurcated,* distance between bifurcations short; the branches also anastomose, or are united by intermediate transverse tubes. Surface of branches smooth or wrinkled; longitudinal striæ sometimes visible around the upper part of the tubes; opening of the tubes nearly round; internal structure very irregular.

The growth of this coral, probably from the action of temporary currents, is singular. The matrix of the specimen is a hard grey limestone, and the slab was about six inches square and an inch and a half thick in the deepest part, gradually thinning off towards the edge. The whole of the under surface was covered with horizontal, ramifying tubes, represented in Pl. 15. f. 11 *a*; but the branches, where space had permitted free growth, regularly bifurcated. The upper surface exhibited tubular openings more or less connected, and this part of the specimen resembled an *Aulopora.* On breaking the slab, vertical, anastomosed or united tubes were exposed (f. 11.) ramifying from the lower to the upper surface; and a connexion could, in some places, be traced between the horizontal branch and the opening on the top of the specimen.

Formation and locality. WENLOCK LIMESTONE, *Dudley.*

*Syringopora filiformis?* (Goldfuss), Pl. 15 *bis.* f. 12 nat. size.

Ref. Goldfuss, Petref. p. 113. Tab. XXXVIII. f. 16.; De Blainville, Man. d'Actinol., p. 353, 1834; Milne Edwards, 2nd Edit. Lamarck, t. 2, p. 328, 1836.

Formations and localities in England. LUDLOW ROCKS, *Ristley Wood near Newent;* WENLOCK LIMESTONE, *Eastnor Park, Ledbury, Prescoed Common, Usk, Aston Ingham near Newent.*

Foreign locality and authority. *Groningen,* Goldfuss.

*Syringopora cæspitosa?,* Goldfuss, Pl. 15 *bis.* f. 13 nat. size, from Mr. Bowerbank's collection.

Ref. Goldfuss, Petref. p. 76. Taf. XXV. f. 9.

Formation and localities in England. WENLOCK LIMESTONE, *Wenlock, Valley of Woolhope.*

Foreign locality and authority. *Paffrath,* beyond *Cöln,* Goldfuss.

CATENIPORA, Lamarck.

*Catenipora escharoides* (Lamarck), Pl. 15 *bis.* f. 14, 14 *a* nat. size, 14 *b* casts of the tubes magnified.

Syn. and Ref. *Millepora,* Fougt, 1745; Linn. Amœn. Acad. t. 1. p. 207. f. 20. 1749.

*Tubipora catenulata,* Gmelin, Linn. p. 3753; Parkinson, Outlines, p. 70. 1822.

*Tubularia catenulata,* Knorr, Recueil, t. 2. pp. 16, 57, 58. Tab. F, IX. F, IX.* f. 4. (*Catenipora tubulosa,* Lamouroux, Exp. Methodiq. p. 65. *note.* 1821) t. 3. p. 158, Supp. Tab. VI. *a.* f. 1. 1775.

*Millepora catenularia*, Esper. Petrificata, Tab. V.; Pflanzenthiere, Erster Theil, s. 260 *note*. 1795.

*Chain coral*, Parkinson, Org. Rem. vol. ii. p. 20. Pl. III. f. 4, 5, 6. 1808.

*Catenipora escharoides* Lamarck, 1st Edit. Anim. sans Vert. tome 2. p. 207. 1816; Lamouroux, Expos. Methodiq. p. 65. 1821; Schweigger, Beobacht. Tab. VII. 1819; Goldfuss, Petref. p. 74. Taf. XXV. f. 4. 1826; Steininger, 1831, Mém. Soc. Geol. France, t. 1. p. 341. 1831; Ehrenberg, 1831, Abhand. 1831, König. Akad. Berlin. p. 344. 1832; De Blainville, Man. d'Actinol. p. 352. Pl. LXII. f. 1. 1834; Milne Edwards, 2nd Edit. Lamarck, t. 2. p. 322. 1836; Hisinger, Lethæa Suecica, p. 94. Tab. XXVI. f. 9, 10. 1837.

*Tubiporites catenarius*, Schlotheim, Petref. p. 366. 1820.

*Halysites*[1] ———, Fischer, Oryc. de Moscow, 1830; *Halysites escharoides*, Bronn, Lethæa Geognostica, p. 52. 1835.

In the series of specimens procured by Mr. Murchison, the tubes vary considerably in size, independently of the age of the bed; and in a specimen, in which they are not more than one-thirtieth of an inch in diameter within the walls of the tubes, the rows or lamellæ are contorted, and very rarely anastomosed. The tubes, in the small varieties, are also in many instances equally oval with those in the larger. It has therefore not been thought necessary to preserve the distinction of two species, *C. escharoides* and *C. labyrinthia*, the latter having been founded on the greater size of the tubes, the contorted arrangement of the rows, and their rarely anastomosing.

Formations and localities in England. MIDDLE LUDLOW ROCK, *Aymestry, Tatter Edge near Downton on the Rock;* WENLOCK LIMESTONE, *Lincoln Hill, Wenlock, Dudley, Fownhope, Newswood in Eastnor Park, Netherlye near Aymestry, Woolhope; Little Ridge, Easthope, West flanks of Malvern Hills;* WENLOCK SHALE AND UPPER BEDS OF CARADOC, *Hughley, Salop, South end of Lickey;* LLANDEILO FLAGS, *Robeston Wathen, and Sholeshook in Pembrokeshire.*

An hemispherical mass sixteen inches in diameter was found at Netherlye, Aymestry, in Wenlock Limestone by the Rev. T. T. Lewis.

Foreign localities and authorities. *Shores of the Baltic*, Fougt; *Gothland*, Knorr, Alex. Brongniart, Goldfuss, Schlotheim, Hisinger; near *Ratofka, Government of Moscow*, Fischer; *Eifel*, Schlotheim, Steininger, Goldfuss; *Drummond Island in Lake Huron*, Bigsby.

PORITES, Lamarck: sub-genus of *Madrepora*, Ehrenberg.

The first of the following species is placed in this genus on the authority of Ehrenberg, and the remainder because they have only twelve rays. It is probable, that it will be found necessary, hereafter, to place some of the species in a distinct genus.

*Porites pyriformis*, (Ehrenberg,) Pl. 16. f. 2, 2*a* to 2*e*.—2, 2*a* upper surface nat. size and magnified, 2*b*, 2*c* horizontal section nat. size and magnified, 2*d* vertical section with the transverse lamellæ, 2*e* vertical section without them.

Syn. and Ref. *Millepora subrotunda*, Fougt, 1745; Linn. Amœn. Acad., t. 1. p. 203. f. 24. 1749.

*Heliolithe pyriforme*, Guettard, Mém., t. 3. p. 454. Pl. 22. f. 13, 14. 1770.

[1] Fischer's generic name of *Halysites* is of anterior date to that of *Catenipora* of Lamarck; but the latter having been generally adopted by zoologists, it has been considered advisable to retain the use of it.

*Madreporites stellatus*, Schlotheim, Petref., p. 362, 1820.

*Astrea porosa*, Goldfuss, Petref., p. 64. Taf. XXI., f. 7. 1826; Hisinger, Lethæa Suecica, p. 98. Tab. XXVIII. f. 2. 1837.

*Astrea interstincta*, Hisinger, Esquisse, Petref. Suède, 2nd Edit. p. 36. 1831.

*Madrepora Porites*, Ehrenberg, 1831; Abhandl. König. Akad. Berlin. p. 344. 1832.

*Heliopora pyriformis*, De Blainville, Man. d'Actinologie, p. 392. 1834; Steininger, Mém. Soc. Geol. France, t. 1. p. 346. 1834; Milne Edwards, 2nd Edit. Lamarck, t. 2. p. 437 *note*. 1836.

*Heliopora interstincta*, Bronn, Lethæa Geognostica, vol. i. p. 48. Tab. V. f. 4. 1835.

Formations and localities in England. AYMESTRY LIMESTONE, OR MIDDLE LUDLOW ROCK, *Aymestry*, *Tatter Edge*; WENLOCK LIMESTONE, *Wenlock Edge*, *Lincoln Hill*, *Benthall Edge*, *Haven near Aymestry*, *Lindells*, *Winslow Mill and Fownhope*, *in the Valley of Woolhope*, *Newswood*, *Eastnor Park*, *and Ledbury*; WENLOCK SHALE, *Delves Green*, *Walsall*; CARADOC SANDSTONE, *Marloes Bay*, *Pembrokeshire*.

Foreign localities and authorities. *Shores of the Baltic*, Fougt; *Gothland*, Schlotheim, Hisinger; *Eifel*, Schlotheim, Goldfuss, Steininger; near *Bensberg*, Goldfuss.

*Porites tubulata*, sp. n. Lons. Pl. 16. f. 3, 3 *a* to 3 *f*.—3, 3 *a* upper surface nat. size and magnified twice, 3 *b* vertical weathered surface, 3 *c*, 3 *d* transverse section nat. size and magnified, 3 *e* vertical section, 3 *f* a small variety nat. size.

P. Hemispherical, stars circular, margin crenated and projecting, rays 12; interstices short lamellæ; transverse section, stars well-defined, rays often indistinct, interstices, lamellæ irregularly united; vertical section, stellular tubes with transverse septa, interstices, lamellæ obliquely united. Under surface rugose, or strongly marked by inequalities of growth; the stellular tubes sometimes exhibited distinctly from the substance of the coral.

Formations and localities. WENLOCK LIMESTONE, *Valley of Woolhope*, *Benthall Edge*, *Ledbury*, *Woodside near Nash Scar*, *Fownhope*, *Western flank of Malvern Hills*, *between Asten Ingham and May Hill*.

*Porites petalliformis*, sp. n. Lons. Pl. 16. f. 4 nat. size, 4 *a* section parallel to the surface nat. size.

P. Hemispherical, star circular, excavated; interstices irregularly laminated, the first row of lamellæ resembling in arrangement the *petals of a flower*. Under surface rugose. Vertical section, with tubes; transverse septa, interstices, lamellæ obliquely united.

Formation and locality. WENLOCK SHALE, *Delves Green*, *Walsall*.

*Porites expatiata*, sp. n. Lons. Pl. 15. f. 3, 3 *a* nat. size and stars magnified.

P. Irregularly lobed, or *spread out*, in layers alternating with sedimentary matter; stars small united, undefined, rays 12; no interstices.

Formations and localities. MIDDLE LUDLOW ROCK, *Aymestry*; WENLOCK LIMESTONE, *Lincoln Hill*, *Colebrook Dale*, *Benthall Edge*, *Wenlock*, *Aston Ingham near May Hill*, *Lindells*, *Woolhope*.

*Porites inordinata*, sp. n. Lons. Pl. 16 *bis*. 12, 12 *a* to 12 *c*.—12 nat. size, 12 *a* stars magnified, 12 *b* casts of the stars, 12 *c* transverse sections of the stems.

P. Branched; branches bifurcated, slender, cylindrical, straight, or curved; stars impressed, *not regularly disposed*, sometimes crowded, sometimes distant, rays twelve, centre united papillæ, interstices reticulated. Internal structure indistinct.

This beautiful fossil generally presents a yellow or cream-coloured crust, exhibiting the above character, and investing a nucleus of grey carbonate of lime. This crust, however, cannot be separated mechanically in the same manner as in recent corticiferous corals. It is insoluble in

muriatic acid; and in the flame of a taper preserves its structure, but assumes a ferruginous colour. Fused with carbonate of soda, it forms a pale greenish enamel. Its developement is apparently due to decomposition. In some specimens it is very thin (see centre stem, f. 12 *c*), in others of great relative thickness, and in this case the inner boundary is generally irregular in outline (upper stem, f. 12 *c*). Occasionally the change has penetrated nearly to the centre of the coral, which then consists of insoluble, reticulated, yellowish fibres, or interrupted lamellæ; and an interval is presented between the matrix and the fossil (right hand stem, f. 12 *c*).

Formation and locality. *Llandeilo Flags, Robeston Walthen, Pembrokeshire.*

*Porites discoidea*, sp. n. Lons. Pl. 16. f. 1 nat. size.

P. *Disk-shaped,* stars not defined, composed of interrupted *lamellæ.*

This specimen is apparently much worn, and from the disposition of the rays it is difficult to count them accurately, but they appear to be twelve in number.

The specimen is in the collection of Mr. Bowerbank.

Formation and locality. WENLOCK LIMESTONE, *Wenlock.*

MONTICULARIA, Lamarck.

*Monticularia conferta,* sp. n. Lons. Pl. 16. f. 5, 5 *a*.—5 upper surface nat. size, 5 *a* vertical weathered surface.

M. Encrusting or expanded in lobes; central axes *close-set,* irregular in size, yet large in proportion to the distance between them; round when single, but several are often united; indications of radiating lamellæ few; under surface when free, uneven, smooth or marked by irregularities of growth.

Formation and localities. WENLOCK LIMESTONE, *Benthall Edge, and Gleedon Hill, near Wenlock.*

ASTREA.

Ehrenberg, in his memoir on the zoophytes of the Red Sea, confines the genus *Astrea* to those corals, the animals of which possess the following characters: "pallio stellas contiguas distinente nullo, disci ipso margine prolifero, ore divisione spontanea bipartito;" and he places those which have contiguous stars, but are quadripartite, "ore divisione spontanea quadripartito," in the genus *Favosites.* This arrangement I have not been able to adopt, with reference to the latter genus, which has been used in this catalogue for corals of a very different description (see *F. Gothlandica,* &c.), and in conformity with the application of approved authorities. In the genus *Astrea,* have therefore been placed the fossils, which exhibit a natural subdivision of the old star, leaving the final determination of their proper arrangement to those who are qualified to make the necessary separations.

*Astrea ananas,* De Blainville, Pl. 16. f. 6, 6 *a* to 6 *f*.—6 nat. size, 6 *a* to 6 *f* developement of young stars, nat. size.

Syn. and Ref. *Madrepora,* Fougt, 1745; Linn. Amœn. Acad. t. 1. p. 196. fig. 8. 1749.

*Madrepora ananas,* Linn. 10th Edit. t. 1. p. 797. 1758; Gmelin, p. 3764; Parkinson, Org. Rem. vol. 2. p. 40. Pl. V. f. 1. 1808.

*Madrepora hexagonatus* ?, Schlotheim, Petref. p. 360. 1820.

*Cyathophyllum ananas,* Goldfuss, Petref. p. 60. Tab. XIX. f. 4. 1826; Milne Edwards, 2nd Edit. Lamarck, t. 2. p. 429. 1836.

*Astrea* (*Favastrea*) *Baltica,* De Blainville, Man. d'Actinologie, p. 375. 1834.

Fig. 6 *a* to 6 *d* beautifully illustrate the subdivision of the old star, and the gradual developement of four young ones. Fig. 6 *a* exhibits the cross lines, marking the subdivision of the animal;

f. 6*b* the first indications of the star; f. 6*c* the formations of the stars considerably advanced; and f. 6*d* the perfectly complete stars. In some instances there are only three young stars, (f. 6*e*, 6*f*), and in others only two (upper part of f. 6). Fig. 6*a*, &c. are from the same specimen.

Formation and locality in England. WENLOCK LIMESTONE, *Dudley*.

Foreign localities and authorities. *Eifel*, *Bensberg*, *Winterberge* near *Grund*, *Finland*, Schlotheim; *Gothland*, Fougt; *Namur*, Goldfuss; between *Colonster* and the *Chaussée de Beaufays*, *Hucergne*, *Province of Liège*, Dumont.

CARYOPHYLLIA, Lamarck.

*Caryophyllia flexuosa* (Lamarck), Pl. 16 f. 7, 7 *a*, 7 *b* nat. size.

Syn. and Ref. *Madrepora*, Fougt, 1745; Linn. Amœn. Acad., t. i. p. 199. fig. 13. n. 5. 1749. *Madrepora flexuosa*, Linn. 10th Edit. t. i. p. 796. 1758; Gmelin, p. 3770; Esper. Petreficata, Tab. VI. 1791.

*Caryophyllia flexuosa*, Lamarck, Anim. sans Vert. 1st Edit. t. 2. p. 227; Steininger, 1831, Mém. Soc. Geol. France, t. 1. p. 342. 1834; Milne Edwards, 2nd Edit. Lamarck, t. 2. p. 352. 1836.

In the two edit. of Lamarck, though the coral is not stated to be fossil, Fougt's figure is referred to. Some confusion has arisen from fossils of different formations, and a recent species, having been assigned to Linnæus's *Madrepora flexuosa*. In the 10th edit. of the Systema Naturæ, and in that of Gmelin, the *Madrepora flexuosa* is confined to the fossil found on the shores of the Baltic, and figured in the Amœnitates Academicæ. Subsequent authors have, however, associated with it a recent coral; and a fossil found in the mountain limestone was called by Parkinson first *Madrepora* and afterwards *Caryophyllia flexuosa* (Org. Rem., t. 2. p. 51. Outlines, p. 73.). But it apparently belongs to a different genus. It is proposed to confine Linnæus's original specific name to the coral which occurs in the Silurian or equivalent strata, and which possesses the generic character of *Caryophyllia* as limited by Ehrenberg; "stellæ palliique divisione perfecta, dichotoma." This character is shown in the section represented in f. 7 *a*. At the line of subdivision there is generally an inequality in the external surface, but the same longitudinal striæ may be traced continuously from the undivided stem to the divided branches.

Formation and locality in England. WENLOCK SHALE, *Malvern*.

Foreign localities and authorities. *Shores of the Baltic*, Fougt; *Eifel*, Steininger.

ACERVULARIA, Schweigger.

*Acervularia Baltica* (Schweigger), Pl. 16 f. 8, 8*a* to 8*e*.—8, 8 *a* upper and under surface, 8 *b* vertical section, 8 *c* to 8 *e* varieties, all nat. size.

Syn. and Ref. *Madrepora*, Fougt, 1745, Linn. Amœn. Acad., t. 1. p. 195. fig. 9. 1749.

*Madrepora ananas*, Linn. 10th Edit., p. 797. 1758; Gmelin, p. 3764.

*Acervularia Baltica*, Schweigger, Beobach. VI. 1819.

*Astrea* (*Favastrea*) *Baltica*, De Blainville, Man. d'Actinologie, p. 375. 1834.

It is presumed that this is the fossil represented by Fougt, though he does not allude in his description to the elevated ridges, which give an apparent boundary to the stars. This character, however, is much stronger in some specimens than in others (f. 8*c* to 8 *e*). Internally the fossil exhibits the union of the stars mentioned by Fougt, "a latere invicem coagmentata et quasi conglutinata." (f. 8 *b*.) The increase or reproduction was not by a natural subdivision of the animal, and therefore this fossil does not belong to the *Astrea* of Ehrenberg. In general

outline the var. 8 *e* strongly resembles the *Cyathophyllum helianthoide* of Goldfuss, but it differs in the rays being narrow not broad, and in the bladder-like or rugose surface, which is not alluded to by that author, or represented in his figures.

Formation and localities in England. WENLOCK LIMESTONE, *Wenlock, Dudley.*

Foreign locality. *Shores of the Baltic,* Fougt.

CYATHOPHYLLUM, Goldfuss.

Only those turbinated corals, which present a central structure resembling the chambers of a *Nautilus,* have been placed in the genus.

*Cyathophyllum turbinatum* (Goldfuss), Pl. 16. f. 11, 11 *a* reduced one-third. Fig. 11 *a* is from a specimen in Mr. Goodhall's collection.

Syn. and Ref. *Madrepora turbinata,* Fougt, 1745, Linn. Amœn. Acad. t. 1. p. 190, f. 2, 3, 7. 1749; Esper. Petrificat. Tab. 2. f. 1–4. 1791—1797; Parkinson, Org. Rem. vol. 2. p. 25–27. Pl. IV. f. 1–3. 1808.

*Caryophylloïde simple,* Guettard, Mém., tome iii. p. 453, 454. Pl. XXII. f. 7, 11. 1770.

*Hippurites,* Knorr, t. ii. part 2. p. 58. Tab. XX. 1775.

*Turbinolia turbinata,* Lamarck, Anim. sans Vert. 1st Edit. t. ii. p. 231. 1816; Schweigger Beobach. Tab. VI. 1819; Lamouroux, Expos. Methodiq. p. 51. 1821; De France, Dic. des Sc. Nat., t. 56. p. 91. 1828; Steininger, 1831, Mém. Soc. Geol. France, t. 1. p. 344. 1831; Hisingér, Lethæa Suecica, p. 100. Tab. XXVIII. f. 6, 7, 8. 1837.

*Hippurites turbinatus,* Schlotheim, Petref., p. 351. 1820.

*Cyathophyllum turbinatum,* Goldfuss, Petref. p. 56. Taf. XVI. f. 8. 1826; Milne Edwards, 2nd Edit. Lamarck, t. 2. p. 428. (remark to *C. ceratites*) 1836; Hisinger, Lethæa Suecica, p. 102. Tab. XXIX. f. 1. 1837.

*Caryophyllia turbinata,* Alex. Brongniart. Tableau des Terr. p. 431. 1829.

Formations and localities in England. WENLOCK LIMESTONE, *Wenlock, Lincoln Hill, Coalbrook Dale, Kinsham, 5 miles west of Aymestry, Ledbury, and West flank of Malvern Hills, Dudley, Valley of Woolhope;* WENLOCK SHALE AND UPPER BEDS OF CARADOC, *Prolimoor Well.*

Foreign localities and authorities. *Gothland,* Fougt, Knorr, Hisinger, Alex. Brongniart; *Eifel,* Schlotheim, Steininger, Milne Edwards, Goldfuss, Alex. Brongniart; *Bensberg,* Goldfuss; *Alleberg in Westgothia,* Hisinger; *Richelle, Liège,* Dumont.

*Cyathophyllum angustum,* sp. n., Lons. Pl. 16. f. 9 nat. size.

C. conical, centre *narrow,* the plates close together and irregular; vesicular side-structure very broad in proportion to the centre, cells small and nearly regular in size.

The section represented in Pl. 9, f. 16 is not parallel throughout to the axis of the coral, only the lower part showing the true centre.

Formation and locality. CARADOC SANDSTONE, (upper calcareous beds of,) *Coal-moors, Lickey.*

*Cyathophyllum cæspitosum* (Goldfuss), Pl. 16. f. 10 reduced one-third.

Ref. Goldfuss Petref. p. 60. Taf. XX. f. 2. 1826. The figures referred to in Guettard (Mém. Tab. 34, 36 and 37.) appear to be doubtful.

Formation and locality in England. WENLOCK LIMESTONE, *Wenlock.*

Foreign localities and authorities. *Eifel and Bensberg,* Goldfuss; *Chokier Seilles, Prov. de Liège,* Dumont.

*Cyathophyllum dianthus,* Goldfuss, Pl. 16. f. 12, 12 *a* to 12 *e* nat. size;—in the upper part of f. 12

are two young germs, in which the star is only developed in part, 12 *d* represents perfectly formed young corals.

Syn. and Ref. *Madrepora,* Fougt, 1745, Linn. Amœn. Acad. t. i. p. 196. f. 10. 1749.

*Madrepora truncata.* Linn. 10th Edit. t. i. p. 795. 1758; Parkinson, Org. Rem. vol. ii. p. 47. Pl. V. f. 2. 1808.

*Strombodes truncatum,* Schweigger, Beobacht. Tab. VI. 1819.

*Madreporites truncatus,* Schlotheim, Petref. p. 355. 1820.

*Cyathophyllum dianthus,* Goldfuss Petref. p. 54. Taf. XV. f. 13, Taf. XVI. f. 1. 1826; Ehrenberg, 1831, Abhandl. Akad. Berlin. 1832, p. 312; Milne Edwards, 2nd Edit. Lamarck, t. ii. p. 427. 1836.

Formations and localities in England. WENLOCK LIMESTONE, *Ledbury, Haven near Aymestry, Wenlock Edge.*

Foreign localities and authorities. *Shores of the Baltic,* Fougt; *Eifel,* Goldfuss, Schlotheim; *Hucogne, Prov. of Liège,* Dumont.

CYSTIPHYLLUM, Lons., *Κύστις* vesica, φύλλον folium.

Turbinated, or cylindrical, fixed, single, or united in groups by secretion from the animal while living. Externally, striated; internally, composed of small *bladder-like* cells. No distinct centre. Terminal cup deep, surface uneven conforming to the shape of the cells, and traversed by interrupted striæ.

This separation from the *Cyathophylla* of Goldfuss appears to be justified by the singularity of the internal structure, and the absence of a distinct centre.

*Cystiphyllum Siluriense.* Lons., Pl. 16 *bis.* f. 1, 1 *a,* 2, nat. size, f. 2 from Mr. Bowerbank's collection.

C. Turbinated, fixed, externally strongly striated, internally composed of cells irregular in form, arrangement, and the thickness of the partitions.

Syn. and Ref. *Cyathophyllum vesiculosum,* Goldfuss, Petref., p. 58. Taf. XVII. f. 5. Taf. XVIII. f. 1. 1826.

Goldfuss's specific character having been adopted to mark the genus, it has been thought necessary to change the specific name.

Formation and localities in England. WENLOCK LIMESTONE, *Wenlock, Dudley.*

Foreign locality and authority. *Eifel,* Goldfuss.

*Cystiphyllum cylindricum,* sp. n. Lons., Pl. 16 *bis.* f. 3, 3 *a,* 3 *b* nat. size.

C. Cylindrical, straight or curved, fixed; externally rugose and striated; internally wholly vesicular; terminal cup deep, surface large protuberances, traversed by dotted rays; no distinct centre.

Formation and locality. *Wenlock Limestone, Benthall Edge.*

STROMBODES, Schweigger.

*Strombodes plicatum* (Ehrenberg). Pl. 16 *bis.* f. 4, 4 *a* to 4 *e.*—4, 4 *a* reduced one-third, 4 *b,* 4 *c* nat. size.

Syn. and Ref. *Cyathophyllum plicatum,* Goldfuss, Petref. p. 59. Taf. XVIII. f. 5. 1826; Milne Edwards, 2nd Edit. Lamarck, t. ii. p. 431. 1836.

*Strombodes plicatum,* Ehrenberg, 1831, Abhandl. König. Akad. Berlin. p. 312. 1832.

This coral is essentially distinguished from *Cyathophyllum* and *Cystiphyllum* by internal structure, the centre consisting not of transverse plates, resembling the septa of a *Nautilus,* or of bladder-like cells, but of lamellæ contorted spirally. In the description of *Strombodes*

by Schweigger and other authors, this structure is not mentioned; it is presumed, nevertheless, that the fossil here represented is a *Strombodes*, and that it is the *S. plicatum* of Goldfuss.

Fig. 4. is from a specimen in the collection of Mr. Bright, Brand Lodge, Malvern.

Formation and locality in England. WENLOCK LIMESTONE, *Western slopes of the Malvern Hills*.

Foreign localities and authorities. *Sweden*, Goldfuss; *Awirs, between Colonster and the Chaussée de Beaufays*, Dumont.

CLADOCORA, Ehrenberg.

*Cladocora sulcata*, sp. n. Lons. Pl. 16 *bis*. f. 9, 9 *a*, 9 *b* nat. size.

C. strongly *furrowed*; terminal star, rays thick; internal structure, lamellæ not symmetrical. On one side of the specimen is a deep cicatrice, presenting no connexion with the interior structure of the stem, but appears to be the point from which a lateral branch has been detached. On the other side (9 *a*) is a small shoot strongly united to the stem by a thick deposit of apparently the original matter of the coral. This specimen is in Mr. Goodhall's cabinet.

Formation and locality. WENLOCK LIMESTONE, *Benthall Edge*.

LIMARIA, Steininger.

*Limaria clathrata* (Steininger), Pl. 16 *bis*. f. 7, 7 *a*, *b*.—7 nat. size, 7 *a*, 7 *b* magnified representations of the openings in different states of contraction and preservation.

Syn. and Ref. *Millepora ramis vagis, punctis imbricatis* ? Fougt, 1745, Linn. Amœn. Acad. p. 202. fig. 14. 1749.

*L. clathrata*, Steininger, 1831, Mém. Soc. Geol. France, t. i. p. 339. Pl. XX. f. 6. 1834.

Formation and locality in England. WENLOCK LIMESTONE, *Dudley*.

Foreign locality and authority. *Eifel*, Steininger.

In the opening or mouth of the tubes, this coral presents great diversity of aspect, due apparently to the degree of contraction and the state of preservation. In the specimen from Shropshire figured in Pl. 16 *bis*, the triangular form given by Steininger is well shown in some parts; while in others, the mouths are merely transverse lines, slightly waved and close together; the surface in both cases being more or less rough, according to its relative perfection. In some portions of the same specimen the branches are confluent or anastomose, and therefore belong to the *L. clathrata* of Steininger; but in others they are long, round and disconnected, and if found separately they might be supposed to belong to his second species, *L. fruticosa*.

In some well-preserved specimens the mouth is open and triangular, the lower part projecting like the raised portion of a coarse file.

*Limaria fruticosa* (Steininger), Pl. 16 *bis*. f. 8, 8 *a* —8 nat. size, 8 *a* mouth magnified.

Ref. Steininger, 1831. Mém. Soc. Geol. France, t. i. p. 339.

Formation and localities in England. WENLOCK LIMESTONE, *Wenlock, Ledbury; Lincoln Hill and Colebrook Dale, Dudley, Nash Scar, Presteign, Abberley Hills*.

Foreign locality and authority. *Eifel*, Steininger.

TURBINOLOPSIS, Lamouroux.

*Turbinolopsis bina*, sp. n. Lons., Pl. 16 *bis*. f. 5, 5 *a* nat. size and vertical lamellæ magnified.

T. turbinated: external cast, perpendicular striæ crossed by transverse lines more or less distinct; internal cast, lamellæ disposed in pairs connected irregularly by transverse distant processes, most numerous towards the base of the cast; lamellæ of each pair also united by close-set processes, thicker and more prominent than the other set.

Formations and localities. LUDLOW ROCKS AND AYMESTRY LIMESTONE, *Bringwood Chase*

*and Downton on the Rock near Ludlow, Botville near Church Stretton.* WENLOCK LIMESTONE AND SHALE, *Newswood, Eastnor Park and West flank of Malvern Hills near Presteign.* Caradoc Sandstone, *Marloes Bay, Pembrokeshire; Goleugoed, Llandovery, Bog Mine Shelve, Salop.*

In the Caradoc Sandstone of the Lickey, casts are found of more than one distinct species, probably belonging to this genus, but the specimens which have been examined were too imperfect to be satisfactorily determined. One of these casts is represented in Pl. 16 *bis.* f. 6, 6 *a.*

CYCLOLITES, Lamarck.

*Cyclolites lenticulata*, Lons. Pl. 15. f. 5, 5 *a.*—5 under surface, 5 *a* upper, 5 *b* section.

C. oval, thin; under surface faint, concentric striæ, traversed by radii; upper surface, broad, tuberculated lamellæ; centre depressed.

Syn. and Ref. *Madrepora, radiis dentatis,* Fougt, 1745, Linn. Amœn. Acad. t. 1. p. 194. fig. 5. 1749.

*Madrepora porpita,* Gmelin, p. 3756; Esper. Petrif. Tab. 1. f. 1—3. 1797.

*Cyclolites numismalis,* Lamarck, Anim. sans Vert. t. ii. p. 233. 1816; Schweigger, Beobach. VI. 1816; De Blainville, Man. d'Actinol. p. 335. Pl. LI. fig. 1. 1834; Milne Edwards, 2nd Edit. Lamarck, t. ii. p. 367. 1836.

*Porpites lenticulatus,* Schlotheim, Petref. p. 350. 1820.

Some confusion having arisen from the *Madrepora porpita* of Gmelin, the fossil of the Baltic, the *Fungia numismalis* of Goldfuss, a coral rag fossil, (see Count F. Mandelsloh, Mém. sur la Constitution géologique de l'Albe du Wurtemberg,) and a recent coral having been included in Lamarck's species *Cyclolites numismalis,* it has been thought advisable to adopt Schlotheim's specific name.

Formation and locality in England. UPPER SILURIAN ROCKS, *Marloes Bay,* clearly overlying the equivalent of the *Wenlock Limestone,* in strata of about the age of the middle Ludlow Rock.

Foreign localities and authorities. *Shores of the Baltic,* Fougt; *Gothland,* Schlotheim.

*Cyclolites præacuta,* Lons. Pl. 15. f. 4 nat. size.

C. oval, very thin: under surface, faint concentric striæ: upper surface, lamellæ sharp-edged, smooth: centre not visible.

Syn. and Ref. *C. numismalis,* Hisinger, Lethæa Suecica, p. 100. Tab. XXVIII. f. 5.

Hisinger has adopted his specific name from Lamarck, but for the reason already given, it has been considered advisable to propose another. This fossil differs also in the form of the lamellæ on the upper surface, from the *Madrepora porpita* of Gmelin and Fougt, the *C. numismalis* of Lamarck. In *C. præacuta* they are sharp-edged and smooth, in *C. lenticulata* or *numismalis* they are broad and tuberculated.

Formation and locality in England. UPPER SILURIAN ROCKS, *Marloes Bay.* Same position as *C. lenticulata.*

Foreign locality. *Shores of Gothland,* and very rarely in the limestone rocks, Hisinger.

VERTICILLIPORA, De France.

*Verticillipora? abnormis,* sp. n. Lons. Pl. 16 *bis.* f. 10, 10 *a* to 10 *d* nat. size. 10 *a* section through the centre of 10, 10 *b* surface pores magnified, 10 *c* apparently younger specimens with a central cavity, 10 *d* part of the surface removed, exhibiting the vertical tubes and an indication of concentric crusts similar to those at the base of f. 10.

V. irregularly branched; centre, hollow, or filled; branches composed of fine contiguous

tubes, traversed by distant septa, and arranged for the greater part parallel to the axis, or slightly diverging from it: surface fine net-work.

This fossil resembles externally De Blainville's figure, Man. d'Actinol., Pl. LXVI. f. 1, of *Verticillipora cretacea* (De France), but no trace has been observed of the peculiar internal structure represented by De Blainville in fig. 1 *a*. It has nevertheless been thought more advisable to place the fossil in the genus *Verticillipora* than to make a new one. The specimens were found by Dr. Cook, of Tortworth.

Formation and locality. UPPER SILURIAN ROCKS, (*Ludlow and Wenlock*, compressed) *Purton Passage*.

CNEMIDIUM, Goldfuss.

*Cnemidium tenue*, sp. n. Lons. Pl. 16 *bis*. f. 11, 11 *a*, 11 *b*.—11 magnified twice, 11 *a* exhibits the centre gravity and the horizontal tubes, 11 *b* surface pores magnified still larger.

C. mammillated or tubular, central gravity large, substance of the fossil thin, radiating horizontal canals or pores distinct and numerous.

Formation and locality. WENLOCK LIMESTONE, *Dudley*.

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## *Graptolites.*

PLATE 26, FIGS. 1, 2, 3 AND 4.

These fossils have been alluded to as good tests of the age of the strata in which they occur. (pp. 206, 309, 326, 401.) It has further been shown, that they are usually found in deposits, which from their structure were well suited to the habits of the family of "sea pens," of which they form a genus. They were named *Graptolites* by Linnæus, and have since been partially described under different names by Wahlenberg, Schlotheim, Hisinger, Nillsson and Bronn. The Danish naturalist Dr. Beck, who is preparing a monograph of them, has supplied me with the following sketch. From his remarks it appears that one of the species, very characteristic of the Upper Silurian Rocks, (Pl. 26. f. 12.) occurs abundantly in Norway and Sweden. Dr. Beck intended to name this species *Graptolithus virgulatus*, but not yet having printed his monograph, he authorizes me to use any other term, and therefore I adhere to the name of *G. Ludensis*, which was adopted before I received the description of the learned Dane[1]. (see p. 206.) It does not, however, appear certain that there is any real distinction between this fossil of the Ludlow Rocks and the *Prionotus sagittarius*, Hisinger, (*Orthoceratites serratus*, Schlotheim). The fossil, fig. 3., is not adverted to by Dr. Beck. It seems most to resemble *Prionotus Folium*, (Hisinger), but differs from that species in the number of foliations, and I therefore venture to suggest the name of *Graptolithus foliaceus*. This species was found in the calcareous flags of Meadow Town near Shelve, Salop (Llandeilo Flags). Fig. 4., of the same plate, being unknown to Dr. Beck, he has, as above stated, named it after me. The *Graptolithus Murchisonii* occurs in the Lower Silurian Rocks, and volcanic grits of the Llandrindod Hills, Radnorshire. (p. 326.)

These pen-like, serrated fossils have a great vertical range in the older or "Protozoic" rocks, being found from the lower part of the Ludlow formation, down to very ancient beds in the Cambrian System, in which they were collected for example by Professor Sedgwick in Abereiddy Bay,

[1] Mr. Lyell, during a recent tour in Denmark, obligingly obtained for me the description of Dr. Beck.

North Pembroke. They there prove by their position, that the lines of slaty cleavage coincide with the original laminæ of deposit, along which these fossils are arranged, p. 461[1].

*Note on Graptolites. By* DR. BECK.

" *Graptolithus,* Linn. Iter Scan. Wahlenberg. Hisinger, &c. *Esquisse d'un Tab. des Petr. de la Suède,* p. 28.

" *Orthoceratites,* Wahlenberg, Schlotheim, Nacht. Pet. 1. p. 56 to 8, f. 3.

" *Priodon,* Nilsson, Bronn, Lethæa Geognostica.

" *Lomatoceras,* Bronn, ib. p. 55.

" *Prionotus Nilsson,* Hisinger Lethæa Suecica, p. 113, 114.

" Very different opinions have been entertained as to the place which the Graptolites hold in the series of living beings, but that of Professor Nilsson may come nearest to the truth, who conceives the Graptolite to be a polyparium of the ceratophydian family. Yet I am more inclined to regard them as belonging to the group *Pennatulinæ,* the Linnæan *Virgularia* being the nearest form in the present state of nature to which they may be compared.

" I am now acquainted with six or seven species of Graptolites, all occurring in the oldest fossiliferous strata, where they are associated with Trilobites, Orthoceratites, &c. Of the species above alluded to, five belong to Scandinavia, and, of the other two, one is peculiar to Bohemian and the other to French strata. The three specimens given me by Mr. Murchison belong to two species, No. 1 and 2 being identical and agreeing with a Norwegian species which in my monograph I have named *Graptolithus virgulatus*; but as the memoir is still unpublished, Mr. Murchison may change the name if he thinks it desirable. The species, No. 4., is new, and Mr. Murchison's name is adopted."

*Generic characters of Graptolithus.*

Class *Polypi.*

Order. Qy. *Octactinia,* Ehrenberg ?

Family. *Pennatulides ?*

Genus. *Graptolithus,* Linn.

" *Polyparium indivisum, elongatum, sublineare, acuminatum, obtusiusculum, statu fossili compressissimum, serratum.*

" *Polypi alternantes cum tubulo communi centrali communicantes, in fossili statu sæpissime secati, rarius bifarii, oblongi, acuminati.*

" When the stem is cut off, the distinct bodies of the single polypes are seen alternating and showing different forms when cut in different directions.

" In the first edition of his Systema Naturæ (1736), Linnæus published a generic group under the name Graptolithus. The first species he described several years afterwards in his travels in Scania (p. 147.), where also a rude figure is given. This is the most common form of graptolites in the Scandinavian transition formations, and as described and named first may be taken as the typical form of the genus. When Linnæus introduced specific names this species of graptolite was

[1] *Graptolites* have recently been found in rocks of the Silurian epoch in Ireland. Capt. Portlock, R.E., has just published, in the first volume of the illustrations of the Ordnance Survey of Ireland, a figure of a beautiful specimen, probably the same species as our *G. Ludensis.*

also named for the first time in the XIIth edition of the Syst. Nat. vol. iii. p. 174. No. 7. as *G. scalaris*.

"In the last-mentioned work the genus Graptolithus is reproduced; but several fossil bodies, and even some inorganic markings and veins in rocks being united as species under the same generic denomination, the real typical form was nearly lost by this intermixture. This confusion was carried still further in the XIIIth edition by Gmelin, where even all the true graptolites were omitted. Wahlenberg restored the genus, all the forms given by him being those fossil bodies which belong to the typical species of the transition formations, but he only gave a superficial account of the subject. Schlotheim referred them to the genus *Orthoceratites*, and several other authors who followed added no original matter. Professor Nilsson of Lund undertook a monograph of the species of graptolites found in Sweden. But he was prevented by circumstances, into which I need not here enter, from continuing his investigations on fossil remains, and some brief remarks only were published by him upon this interesting genus in the proceedings of the Physiographical Society of Lund. In that notice he proposed a new name for the genus, altering it to that of *Priodon*, a name not only objectionable as being unnecessary, but as having been already employed by Cuvier for a genus of *Acanthopterygian* fishes of the family *Teuthidæ*.

"Since that time no attempt has been made to write a monograph. Professor Bronn of Heidelberg in his Lethæa Geognostica, again, however, changed the name of the genus to *Lomatoceras*, a name already given to an insect[1]."

## NONDESCRIPTS.

*Spongarium Edwardsii*. Pl. 26. f. 10.

This singular fossil has not been described by any English naturalist. I had not, indeed, met with any one who could throw light upon its probable origin, until, in 1836, I showed it to Dr. Milne Edwards, who was then on a visit to this country; on which occasion he took a sketch of the specimen, and has since favoured me with the following description, extracted from his note-book.

"The nature of the orbicular fossil is very problematic. At first sight it might be taken for a cartilage of *Velella*, or for some marine plant bearing an analogy to *Zonaria pavonia* (D'Agarth), or still more probably for a *Cyclolite* of Lamarck, all the superior portion of which may be supposed to have disappeared in the stony matrix, and the inferior surface of which only has remained visible. In fact, many small ridges or obtuse cristæ may be observed on it, which, radiating from a common centre, are crossed by salient circular lines, similar rather to membranaceous folds than ribs (côtes). On examining, however, more closely these objects, we perceive that all these analogies are erroneous; for the radiating ribs of this fossil are not straight lines, between which, in proportion as they widen out, other and similar lamellæ are developed (as in the *Cyclolites*, &c.); but they ramify irregularly, in extending from the central point.

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1 In consequence of the views of Dr. Beck, and sanctioned by the advice of Mr. Lonsdale, I have inserted the Graptolites in the list of *Polyparia*, between the genera *Limaria* and *Cladocora* (see p. 711).

A beautifully illustrated book on the Swedish fossils has recently been published by Hisinger, in which the generic name of Nilsson "*Prionotus*" has been continued. The highly useful work of Bronn was, I regret to say, unknown to me till too late to be referred to in the description of many of the other fossils.—R.I.M.

"This fossil is most analogous to a very singular body described by Lamarck under the name of *Spongia Labellum.* The *Spongia Labellum* cannot remain among the Sponges, properly so called, but ought to form the type of a particular genus. It is composed of rather slender, foliaceous laminæ, arranged in an infundibuliform manner, and formed of cylindrical, longitudinal and slender shoots (tigelles), which ramify and anastomose among each other, and are covered by a kind of parenchymatous membrane which occupies equally the meshes left by this tissue.

"In short, I believe that this fossil of the Ludlow Rocks ought to form the type of a particular genus in the great family of *Sponges,* and may be characterized provisionally as follows, until the structure of the body is studied.

"A foliaceous, orbicular body, attached by its centre, and presenting a great number of salient, divergent ridges, which divide successively into several centrifugal branches, and appear to be covered by a membrane having circular and concentric folds."—*Translation and Extract of a letter from Dr. Milne Edwards.*

Loc. *Bircher Common, near Aymestry,* where it was found in the Upper Ludlow Rock by the Rev. T. T. Lewis.

*Cophinus dubius,* Pl. 26. f. 12.

This is a nondescript fossil concerning the origin of which no naturalist has yet given a decisive opinion. It has been referred with doubts to the family of soft *Zoophytes, Crinoidea,* and to *Mollusca;* so wide from each other are the guesses as to its place in the natural order[1]. All we can say with certainty is, that it has *the shape of an inverted four-sided pyramid, with a column-like rounding off at each corner, and 4 intercolumniations or sides, transversely situated, producing the appearance of basket-work;* whence, whatever it may prove to be, the fossil is provisionally named, at the suggestion of Mr. König, *Cophinus* (wicker basket). This curious body has been adverted to in the text (p. 181.) as occurring in positions more or less *vertical* in the uppermost strata of the Ludlow Rock, from which I infer that the animal was attached by the end of the inverted cone, while the finely levigated muddy sediment accumulated around the columns or stems.

I am indebted to Mr. W. Evans not only for collecting the best specimens of *Cophinus* with which I am acquainted, but also for directing my attention to the vertical position of the fossil in the Upper Ludlow Rock. As the drawing in the wood-cut was taken from an imperfect and broken specimen, I have in this plate given a more perfect representation of the fossil.

*Ischadites Königii,* Pl. 26. f. 11.

These curious fossils are so grouped together, that I always compared them with "packed or pressed figs;" and Mr. König, to whom I referred them, thus speaks of them. "I am of opinion that they may be considered to belong to the family of *Ascidiæ.* Like the *Leucophthalmus* of the Icones Sectiles (Cent. 1. f. 1.), they seem to form a group of globular, coriaceous, and, it may be added, pedicled bodies, for in one of them the cicatrix for the insertion of the pedicle distinctly appears. As, however, no traces of branchial and intestinal apertures are apparent on the surface exposed to view, it would be rash to constitute this fossil a genus, or to assign it a place in any of the known genera of the order of the naked Mollusca, to which *Leucophthalmus* unquestionably belongs."

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[1] When the Chapters on the Ludlow Rock were printing, I was led to consider the *Cophinus* a soft Zoophyte, allied to "Sea Pens." See p. 206.

Unable to acquire more knowledge concerning the affinities of this fossil, I simply refer to the figure, in which the beautiful tesselation of its surface is expressed; and feeling that any name, which does not mislead, is better than no name, I have called it *Ischadites,* from ἰσχὰς, a dried or potted fig, the specific name being furnished by my friend Mr. König, who, as above stated, has described animals somewhat analogous. (See *Leucophthalmus, Icones Fossiles,* Cent. 1. f. 1.)

Loc. *Ludlow* (Lower Ludlow Rock). Found by Dr. Lloyd, to whom I am so deeply indebted for many of the fossils engraved in this work[1].

*Polymeres Demetarum,* Pl. 26. f. 13.

This fossil, which occurs in dull black shale with the *Ogygia Murchisoniæ,* Pl. 25. f. 3, consists of a cylindrical, longitudinally divided tube, cut transversely into short pieces or segments, the edges of which are inclined. The joints are parallel and cylindrical, and instead of forming regular circles, are bent into several arcs: both surfaces are smooth. The tubes in various specimens are crushed transversely, obliquely, or longitudinally according to their position in the rock, and in the same direction as the trilobites and other organic remains of the mass. As the segments appear to be entire cylinders, the tubes may be the remains of animals resembling *Iulus* or *Oniscus.* It is probable that the matrix was once filled with pyrites, which in decomposing has left only black oxyd of iron and stellated groups of crystals of gypsum.

Loc. *Pensarn or Mount Pleasant on the left bank of the Towy, near Caermarthen.*

These tubular bodies were discovered with the *Ogygia Murchisoniæ* in the above locality. I have named them after the county in which they occur[2].

## FUCOIDS.

To the figures of fossils, whose place in the natural kingdom is not easily determined, I might have added the drawings of certain indistinct fucoids. The best preserved, however, of these specimens does not express more than the small figure already given by Mr. Yates in the Transactions of the Geological Society, vol. ii. New Series, Pl. 27. The specimens I collected were examined by Mr. Robert Brown and Dr. Greville, but neither of these eminent botanists are able to say much more than that they are fucoid-like bodies.

They chiefly occur in Caradoc Sandstone, or in the beds of passage between that formation and the Wenlock Shale. They are found in the latter position on the eastern side of the Lower Lickey Hills, and in true Caradoc Sandstone at Ankerdine Hill, Worcestershire: the species at these two localities are distinct.

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[1] The *Cornularius Serpularius,* Schloth., of the Wenlock Limestone, and of which four figures are given Pl. 26. figs. 5 to 9. is fully described, p. 627, though without being placed in its natural position in the animal kingdom. In like manner, the *Tentaculites,* Schloth., of which four species are described, pp. 613, 628, 643. Pl. 5. f. 33. Pl. 12. f. 25. Pl. 19. figs. 15 and 16., is not yet referred to any known animal, and is therefore arranged in the general table with the other forms whose place is uncertain.

[2] Demetæ, Caermarthenshire.

Having previously alluded to certain convoluted forms in the Cambrian Rocks of Llampeter, p. 363, which were not then referred to any known organized body, I have now to acquaint my readers that having submitted them to Mr. W. MacLeay, he has pronounced them to have been "sea worms," and has favoured me with the following description, prefaced by a short general view of their place in the animal kingdom. The *Serpulites longissimus*, a well-known fossil of the Upper Ludlow Rocks (see pp. 200 and 608.), with the nature of which we were previously unacquainted, is thus assigned to its proper place among the *Annelida*. See p. 699. Mr. MacLeay has permitted me to affix specific names to the forms in the Cambrian Rocks described by him; viz.

*Nereites Cambrensis*, so named from the rocks in which it occurs.

——— *Sedgwickii*, from the geologist who illustrates the Cambrian System.

*Myrianites Macleayii*, after the naturalist who describes these fossils.

*Nemertites Ollivantii*, after their discoverer. (See p. 363 and Table p. 714.)

Loc. *Llampeter, Caermarthenshire.* In the schistose building-stone of that place, in which they were found by the Rev. A. Ollivant, Professor of Llampeter College.

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### *Note on the Annelida. By* W. S. MacLeay, M.A. F.L.S. &c.

These animals differ from true *Annulosa* in being hermaphrodite, and in general red-blooded[1]. They are soft vermiform animals of an articulated structure, and which form the immediate connexion between such *Vertebrata* as *Amphioxus* and *Myxine*, and such *Annulosa* as *Porocephalus* and other white-blooded *Vermes*, which have the sexes distinct.

I divide the *Annelida* as follows:

ANNELIDA.

| | | |
|---|---|---|
| Normal Group. | | |
| Polypoda. Marine animals, having their body provided with distinct feet. | Nereidina. | Animals free, having a distinct head provided with either eyes or antennæ or both. |
| | Serpulina. | Animals sedentary, and having no head, provided with eyes or antennæ. |
| Aberrant Group. | | |
| Apoda. Body without feet or a distinct head. | Lumbricina. | Animals without eyes or antennæ. Body externally setigerous for locomotion. Articulation distinct. |
| | Nemertina. | Animals aquatic, without eyes or antennæ. Body not externally setigerous. Articulation indistinct. |
| | Hirudina. | Animals provided generally with eyes but not with antennæ. Body not externally setigerous. Articulation distinct. |

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[1] Milne Edwards is said in the public journals to have discovered that some *Annelida* are not provided with red blood, but the distinguished Savigny stated the same fact so long ago as the year 1823, for in his *Système des Annelides* he places *Clepsine* among his *Hirudinées*. Nay, even Cuvier, who first distinctly pointed out the group under the name of *vers à sang rouge*, has said that their blood is only generally red. Although hermaphrodites, many of them require a reciprocal coitus.

### NEREIDINA, MacLeay.

These are the most perfect in their structure of all *Annelida,* as they possess numerous organs and have a distinct head, which is generally provided with eyes and antennæ. Some of them, after the manner of *Serpulina,* inhabit tubes, which tubes are membranaceous, and formed by a transudation from their body; but in general the *Nereidina* are naked, and they are always agile animals freely moving about in search of their prey. Aristotle calls them, "Σκολόπενδραι θαλάσσιαι παραπλήσιαι τῷ εἴδει ταῖς χερσαίαις," (Lib. ii. c. 121.); and it is true that they are wonderfully like Centipedes. The fossil impressions in the Llampeter Rocks, are too indistinct to enable us to determine very accurately the genera and species of *Nereidina* which there occur, more particularly as the generic characters in this group depend on such minute distinctions as are afforded by a study of the mouth, antennæ and eyes. I shall therefore consider the impressions fig. 1. and fig. 2. to belong to the

Genus NEREITES. A genus which comes very near to Savigny's genus *Lycoris* in its external appearance, only the segments of the body are here perhaps more slender and in proportion longer than usual.

Spec. 1. *Nereites Cambrensis.* Murch. *n. s.*

The body of this species seems to have consisted of about 120 segments. The feet were half the length of a segment of the body, and the cirri of the feet were longer than such segment.—Plate 27. Fig. 1.

Spec. 2. *Nereites Sedgwickii.* Murch. *n. s.*

Body much more slender than that of *N. Cambrensis,* and apparently consisting of a greater number of segments. These segments have the feet attached to them apparently inconspicuous, although the cirri are very distinct. Plate 27. fig. 2.

N.B. The impression now under consideration was clearly that of an animal, as will appear by the figure, where the worm has evidently, before coiling, with difficulty trailed itself along in the mud, in a way, which any one accustomed to collect these *Annelida* will at once recognise.

Genus MYRIANITES.

Body linear, very narrow, and formed of very numerous segments with indistinct feet and short cirri.

Spec. 1. *Myrianites MacLeaii.* Murch. *n. s.*—Plate 27. Fig. 3.

N.B. The softness of the texture of the foregoing three species of *Annelida* and the perfection of the impression in fig. 1. make it very remarkable, that if articulated feet existed in the Trilobites, some vestiges of them, even although membranaceous, should not have come down to us more perfect than those figured by Goldfuss. (See Ann. Scienc. Nat. vol. xv. Pl. 2. f. 8. and pp. 665, 667 *ante.*)

### SERPULINA, MacLeay.

These are sedentary animals without eyes or antennæ. They live in tubes which are either a natural transudation of their body, and are either membranaceous or calcareous, or their tubes are semifactitious, being then composed of an agglutination of particles of sand or other small substances. The calcareous nature of the tube in some *Serpulina* is very advantageous for their preservation, and has thus enabled us to see that such animals occurred frequently in the Upper Silurian Rocks.

Genus SERPULITES.

Spec. 1. *Serpulites longissimus.* Murch. *n. s.* Pl. 5. f. 1.

(See previous description of this very characteristic fossil of the Upper Ludlow Rock, p. 608.)

NEMERTINA, MacLeay.

The *Nemertina* are white-blooded worms like some of the *Hirudina* or *Leeches.* In this group, however, the character of articulation becomes most indistinct. Rudolfi has placed *Gordius* along with *Nemertes* (Ent. Syst. 572.); and if *Gordius* goes into the group of *Nemertina,* it is possible that *Filaria* may also. *Nemertes Borlasii,* is a long black sea-worm, which is said to suck Testaceous *Mollusca.* The articulations of its body become visible when it is contracted. If the long vermiform impression in the Cambrian Rocks of Llampeter, Plate 27. f. 4. belong to organic substances, it can only be referred to some animal between *Gordius* and *Nemertes,* although probably nearer the former genus. As yet, however, *Gordii* are only known to occur in fresh water, whereas this fossil production, if it belong to the animal kingdom, was evidently like *Nemertes,* a native of the sea.

Genus NEMERTITES ?

Animal marine, with the linear body, of a *Gordius* or *Filaria.*

Spec. 1. *Nemertites Ollivantii.* Murch. *n. s.*—Plate 27. Fig. 4.

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*Postscript.*—I have said, that much examination is required to establish accurate comparisons between the Silurian Rocks of England and of other countries. We may, however, observe, that as a certain number of Silurian shells have a wide range in foreign lands, so it may be hoped, that subsequent inquiry will lead to many more identifications. If, indeed, the lists here presented are appealed to, we should say, that the fossils of the Upper Silurian Rocks only, particularly those of the Wenlock formation, had hitherto been much examined by continental authors, since nearly all the forms in their works which we have been able to assimilate to those of our own country, occur in the Upper Silurian group. Thus, while scarcely more than five or six of the Lower Silurian fossils can be compared with published foreign species, we find among the latter a considerable number of Trilobites, Mollusks and Corals, which are common in our Wenlock formation, and a few in the Ludlow Rocks. This comparison is particularly applicable to the Corals: a certain proportion of them have been figured from calcareous rocks in Sweden, Norway and Germany, which are thus placed in direct parallel with the Wenlock limestone. As, however, the fossils of the Upper Ludlow Rock seem to have been little more discovered than those of the Lower Silurian group, are we hence to infer that these fossiliferous deposits, which in England and Wales exhibit transitions or passages from the Silurian system, both in ascending and descending order, are of rare occurrence on the continent, or that the deficiency results from inadequate examination? Further inquiry can alone determine this point.

In regard, however, to the diffusion of Silurian deposits over still more distant regions, I may add, that I am more than ever convinced of their existence in Southern Africa. (See p. 585.) Captain (now Sir James) Alexander, whose travels have been referred to, p. 653, has recently laid before me a collection of rock specimens collected by himself, and I have no scruple in affirming that the brownish coloured sandstone, which rises to the highest points of the Cedar Mountains, north of the Cape Colony, is a "Lower Silurian" Rock; for it is loaded with casts of an *Orthis,* very closely resembling the *Orthis callactis,* associated with *Bellerophon acutus, Tentaculites annulosus,* Schloth., and many crinoidal stems, &c. Thus, while the *Homalonoti* and other fossils found in the ravines and on the slopes of these mountains led me to suppose that they were composed of Upper Silurian Rocks, this fresh importation of specimens in convincing me that the axis of the chain is Lower

Silurian (mineralogically, indeed, true Caradoc Sandstone), demonstrates a succession similar to that of our own country, and completes the parallel of these South African formations with those of England[1].

To whatever extent such identifications may hereafter reach, I hope that, in the mean time, the present contribution may, to some extent, enable foreign geologists to compare their older fossiliferous or "Protozoic" strata with those of Great Britain.

Allusion has already been made, p. 643, to the substitution of the word *Leptæna* for ***Productus***. I must also observe, that upon comparing certain descriptions of the rocks with the subsequent pages in which the organic remains are described, the reader will detect a slight want of agreement in the names of a few other fossils; a discrepancy caused by changes made during the progress of the work. Again, the vertical range of three or four fossils through various deposits is incompletely given in the descriptive part; but such omissions are, it is hoped, corrected in the following table of the Organic Remains.

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*Obs.* To the description of the *Crinoidea* (p. 671.) by Professor Phillips, I omitted to add the names of some of the persons who had contributed to the illustration of this work by the loan of specimens. The beautiful fossil *Cyathocrinites goniodactylus* (Pl. 17, f. 1.), was selected from the choice cabinet of my friend the Marquis of Northampton. This specimen exhibits very distinctly the round branches near its root or base, by which the animal was attached. The remarkable *Actinocrinites? expansus* (Pl. 17, f. 9.), belongs to Mr. B. Bright. Mrs. Downing communicated the specimens (Pl. 17, f. 4, 6 and 8, and Pl. 18, f. 3 and 7.); and the other forms, with the exception of *Hypanthocrinites decorus*, alluded to p. 673, are to be seen in the cabinets of Mr. Bright, Mr. H. W. Inwood, and myself.—*R. I. M.*

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[1] It may further be stated, that among the fossils from the Cedar Mountains, is a true *Calymene Tristani*, Brongn., and a fragment of the head of *Homalonotus Herschelii* (nob.), so large, that the whole animal can scarcely have been less than the *Asaphus tyrannus*, var. *ornata*, nob. Pl. 24.

# TABULAR LIST OF ORGANIC REMAINS IN THE OLD RED SANDSTONE AND SILURIAN ROCKS.

TABULAR List of the Organic Remains in the Old Red Sandstone and Silurian Rocks, commencing with fishes and terminating with zoophytes. The formation in which each species occurs is indicated by an *. Every fossil to which no author's name is attached is considered to be a new species, being figured for the first time in this work. Of these, the fishes are described by M. Agassiz, the crustaceans by Mr. Murchison, the shells by Mr. J. de C. Sowerby, the encrinites by Professor Phillips, and the corals by Mr. Lonsdale. Mr. Broderip, Mr. W. Macleay, Dr. Milne Edwards, and Mr. König, have also contributed.

(The following abbreviations of authors' names are employed in the table. *Ag.*, Agassiz. *Brongn.*, Alexander Brongniart. *Dalm.*, Dalman. *De Blainv.*, De Blainville. *Ehr.*, Ehrenberg. *His.*, Hisinger. *Kön.*, König. *Lam.*, Lamarck. *Lamx.*, Lamouroux. *Mill.*, Miller. *M. C.*, Mineral Conchology of Sowerby. *Sow.*, Sowerby. *Pent.*, Pentland. *V. Buch*, Von Buch. *Schweig.*, Schweigger. *Stein.*, Steininger. *Val.*, Valenciennes.)

| Number of species. | GENUS AND SPECIES. | Description and Figure in this work. | | Old Red Sandstone (middle and lower beds only.) | SILURIAN ROCKS. | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Upper. | | | | | Lower. | |
| | | Plate and Figure. | Page. | | Upper Ludlow Rock. | Aymestry Limestone. | Lower Ludlow Rock. | Wenlock Limestone. | Wenlock Shale. | Caradoc Sandstone. | Llandeilo Flags. |
| | PISCES. | | | | | | | | | | |
| 1 | Cephalaspis Lyellii, *Ag.* | I. 1 to 8. II. 1, 2 and 3. | 589 | * | .. | .. | .. | .. | .. | .. | .. |
| 2 | ——— rostratus, *Ag.* | II. 4 and 5. | 592 | * | .. | .. | .. | .. | .. | .. | .. |
| 3 | ——— Lewisii, *Ag.* | II. 6. | 593 | * | .. | .. | .. | .. | .. | .. | .. |
| 4 | ——— Lloydii, *Ag.* | II. 7 to 9. | 594 | * | .. | .. | .. | .. | .. | .. | .. |
| 1 | Cheiracanthus Murchisoni, *Ag.* | not figured. | 601 | * | .. | .. | .. | .. | .. | .. | .. |
| 2 | ——— minor, *Ag.* | ——— | — | * | .. | .. | .. | .. | .. | .. | .. |
| 1 | Cheirolepis Traillii, *Ag.* | ——— | — | * | .. | .. | .. | .. | .. | .. | .. |
| 2 | ——— uragus, *Ag.* | ——— | — | * | .. | .. | .. | .. | .. | .. | .. |
| 1 | Ctenacanthus ornatus | II. 14. | 597 | * | .. | .. | .. | .. | .. | .. | .. |
| 1 | Dipterus macrolepidotus, *Sedgw. & Murch.* | not figured. | 599 | * | .. | .. | .. | .. | .. | .. | .. |
| 1 | Diplopterus, *Ag.* | ——— | 601 | * | .. | .. | .. | .. | .. | .. | .. |
| 1 | Holoptychus Nobilissimus | II. *bis.* 1 and 2. | 599 | * | .. | .. | .. | .. | .. | .. | .. |
| 1 | Onchus arcuatus, *Ag.* | II. 10 and 11. | 596 | * | .. | .. | .. | .. | .. | .. | .. |
| 2 | ——— semi-striatus, *Ag.* | II. 12 and 13. | — | * | .. | .. | .. | .. | .. | .. | .. |
| 3 | ——— Murchisoni, *Ag.* | IV. 9 to 11. | 607 | .. | * | .. | .. | .. | .. | .. | .. |
| 4 | ——— tenuistriatus, *Ag.* | IV. 57 to 59. | — | .. | * | .. | .. | .. | .. | .. | .. |
| 1 | Osteolepis macrolepidotus, *Val. & Pent.* | not figured. | 601 | * | .. | .. | .. | .. | .. | .. | .. |
| 2 | ——— microlepidotus, *Val. & Pent.* | ——— | — | * | .. | .. | .. | .. | .. | .. | .. |

| Number of species. | Genus and Species. | Description and Figure in this work. Plate and Figure. | Page. | Old Red Sandstone (middle and lower beds only.) | Silurian Rocks. Upper. Upper Ludlow Rock. | Aymestry Limestone. | Lower Ludlow Rock. | Wenlock Limestone. | Wenlock Shale. | Lower. Caradoc Sandstone. | Llandeilo Flags. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Ptychacanthus ? | I. 9. and 10. | 597 | * | .. | .. | .. | .. | .. | .. | .. |
| 1 | Pterygotus problematicus | IV. 4 and 5. | 606 | .. | .. | .. | * | .. | .. | .. | .. |
| 1 | Plectrodus mirabilis | IV. 14 to 26. | — | .. | * | .. | .. | .. | .. | .. | .. |
| 1 | Thelodus parvidens | IV. 34 to 36. | — | .. | * | .. | .. | .. | .. | .. | .. |
| 1 | Sphagodus pristodontus | IV. 1, 2, 3 & 6. | — | .. | * | .. | .. | .. | .. | .. | .. |
| 1 | Sclerodus pustuliferus | IV. 27 to 32, & 60 to 62. | — | .. | * | .. | .. | .. | .. | .. | .. |
| 1 | Coprolites of Plectrodus, &c. | IV. 46 to 55. | 607 | .. | * | .. | .. | .. | .. | .. | .. |
| | CRUSTACEA. | | | | | | | | | | |
| 1 | Homalonotus Knightii, *Kön.* | VII. 1 & 2. | 651 | .. | * | .. | .. | .. | .. | .. | .. |
| 2 | ——— Ludensis | VII. 3 & 4. | — | .. | * | .. | .. | .. | .. | .. | .. |
| 3 | ——— Herschelii | VII. *bis.* 2. | 652 | .. | * ? | .. | .. | .. | .. | .. | .. |
| 4 | ——— delphinocephalus, (Trimerus delphinocephalus ? *Green.* | VII. *bis.* 3 *a*, *b*, *c* & *d.* | 651 | .. | .. | .. | * | * | .. | .. | .. |
| 1 | Calymene Blumenbachii, *Brongn.* | VII. 5 to 7. | 653 | .. | .. | * | * | * | .. | .. | .. |
| 2 | ——— ? Downingiæ | XIV. 3 *a* & *b.* | 655 | .. | .. | .. | .. | * | .. | .. | .. |
| 3 | ——— tuberculata | XIV. 4. | 656 | .. | .. | .. | .. | * | .. | .. | .. |
| 4 | ——— macrophthalma, *Brongn* | XIV. 2. | 655 | .. | .. | .. | .. | * | .. | .. | .. |
| 5 | ——— variolaris, *Brongn.* | XIV. 1. | — | .. | .. | .. | .. | * | .. | .. | .. |
| 6 | ——— ? punctata, *Wahl.* | XXIII. 8. | — | .. | .. | .. | .. | .. | .. | * | .. |
| 1 | Asaphus caudatus, *Brongn.* | VII. 8 *a.* | 654 | .. | | * | * | * | * | .. | .. |
| 2 | ——— tuberculato-caudatus | VII. 8 *b.* | — | .. | .. | .. | .. | * | .. | .. | .. |
| 3 | ——— sub-caudatus | VII. 10. | 655 | .. | * | * | .. | .. | .. | .. | .. |
| 4 | ——— longi-caudatus | XIV. 11 to 14. | 656 | .. | .. | .. | .. | .. | * | .. | .. |
| 5 | ——— Cawdori | VII. 9. | 655 | .. | * | .. | .. | .. | .. | .. | .. |
| 6 | ——— flabellifer, *Stein.* | not figured. | 654 | .. | .. | .. | .. | * | .. | .. | .. |
| 7 | ——— Stokesii | XIV. 6. | 656 | .. | .. | .. | .. | * | .. | .. | .. |
| 8 | ——— Powisii | XXIII. 9 *a*, *b* & *c.* | 661 | .. | .. | .. | .. | .. | .. | * | .. |
| 9 | ———? duplicatus | XXV. 8. | — | .. | .. | .. | .. | .. | .. | * | .. |
| 10 | ——— Vulcani | XXV. 5. | 663 | .. | .. | .. | .. | .. | .. | .. | * |
| 11 | ——— Corndensis | XXV. 4. | — | .. | .. | .. | .. | .. | .. | .. | * |
| 12 | ——— Buchii, *Brongn.* | XXV. 2. | 662 | .. | .. | .. | .. | .. | .. | .. | * |
| 13 | ——— Tyrannus | XXV. 1 *a* & *b.* | — | .. | .. | .. | .. | .. | .. | .. | * |
| 14 | ——— Tyrannus, *var.* ornata | XXIV. | — | .. | .. | .. | .. | .. | .. | .. | * |
| 1 | Acidaspis Brightii | XIV. 15. | 658 | .. | .. | .. | .. | * | .. | .. | .. |
| 1 | Bumastus Barriensis | VII. *bis.* 3 *a* to *d.* XIV. 7. | 656 | .. | .. | .. | .. | * | .. | .. | .. |
| 1 | Paradoxides 2-mucronatus | XIV. 8 and 9. | 658 | .. | .. | .. | .. | * | .. | .. | .. |
| 2 | ——— 4-mucronatus | XIV. 10. | — | .. | .. | .. | .. | * | .. | .. | .. |
| 1 | Illænus ? perovalis | XXIII. 7 *a* & *b.* | 661 | .. | .. | .. | .. | .. | .. | * | * |
| 1 | Trinucleus Caractaci | XXIII. 1 *a* to *f.* | 659 | .. | .. | .. | .. | .. | .. | * | .. |
| 2 | ——— fimbriatus | XXIII. 2. | 660 | .. | .. | .. | .. | .. | .. | * | * |
| 3 | ——— radiatus | XXIII. 3 *a* & *b.* | — | .. | .. | .. | .. | .. | .. | * | .. |
| 4 | ——— Lloydii | XXIII. 4. | — | .. | .. | .. | .. | .. | .. | * | .. |
| 5 | ——— nudus | XXIII. 5. | — | .. | .. | .. | .. | .. | .. | .. | * |
| 6 | ——— Asaphoides | XXIII. 6. | — | .. | .. | .. | .. | .. | .. | .. | * |
| 1 | Ogygia Murchisoniæ | XXV. 3 *a* & *b.* | 664 | .. | .. | .. | .. | .. | .. | .. | * |
| 1 | Agnostus pisiformis ? *Brongn.* | XXV. 6 *a* & *b.* | — | .. | .. | .. | .. | .. | .. | .. | * |

| Number of species. | Genus and Species. | Description and Figure in this work. Plate and Figure. | Description and Figure in this work. Page. | Old Red Sandstone (middle and lower beds only.) | Silurian Rocks. Upper. Upper Ludlow Rock. | Silurian Rocks. Upper. Aymestry Limestone. | Silurian Rocks. Upper. Lower Ludlow Rock. | Silurian Rocks. Upper. Wenlock Limestone. | Silurian Rocks. Upper. Wenlock Shale. | Silurian Rocks. Lower. Caradoc Sandstone. | Silurian Rocks. Lower. Llandeilo Flags. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | **ANNELIDA.** | | | | | | | | | | |
| 1 | Serpulites longissimus | V. 1. | 608 | .. | * | .. | .. | .. | .. | .. | .. |
| 1 | Spirorbis tenuis | VIII. 1. XI. 8. | 616 | .. | .. | .. | * | * | .. | .. | .. |
| | *Obs.* Other Annelida occur in the upper Cambrian Rocks. See pp. 699, 700. | | | | | | | | | | |
| | **MOLLUSCA.** | | | | | | | | | | |
| | *Ord.* Heteropoda. | | | | | | | | | | |
| 1 | Bellerophon carinatus | III. 1 *d*, 4. | 604 | * | * | .. | .. | .. | .. | .. | .. |
| 2 | ——— striatus | III. 12 *e*. | — | * | .. | .. | .. | .. | .. | .. | .. |
| 3 | ——— globatus | III. 15. IV. 50. | {604 613} | * | * | .. | .. | .. | .. | .. | .. |
| 4 | ——— trilobatus | III. 16. | 604 | * | .. | .. | .. | .. | .. | .. | .. |
| 5 | ——— ——— var. | XXI. 21. | 643 | .. | .. | .. | .. | .. | .. | * | .. |
| 6 | ——— expansus | V. 32. | 613 | .. | * | .. | .. | .. | .. | .. | .. |
| 7 | ——— Aymestriensis | VI. 12. | 616 | .. | .. | * | .. | .. | .. | .. | .. |
| 8 | ——— dilatatus | XII. 23 & 24. | 627 | .. | .. | .. | .. | * | .. | .. | .. |
| 9 | ——— Wenlockensis, (B. apertus, in the text) | XIII. 21. | 627 | .. | .. | .. | .. | * | .. | .. | .. |
| 10 | ——— bilobatus | XIX. 13. | 643 | .. | .. | .. | .. | .. | .. | * | * |
| 11 | ——— acutus | XIX. 14. | 643 | .. | .. | .. | .. | .. | .. | * | .. |
| | *Ord.* Cephalopoda. | | | | | | | | | | |
| 1 | Nautilus undosus | XXII. 17. | 642 | .. | .. | .. | .. | .. | .. | * | .. |
| 1 | Lituites tortuosus | XI. 3. | 622 | .. | .. | .. | * | .. | .. | .. | .. |
| 2 | ——— giganteus | XI. 4. | — | .. | .. | * | * | * | .. | .. | .. |
| 3 | ——— articulatus | XI. 5 and 7. | — | .. | .. | .. | * | .. | .. | .. | .. |
| 4 | ——— ? Ibex (see Orthoceras Ibex) | XI. 6. | — | .. | .. | .. | * | .. | .. | .. | .. |
| 5 | ——— ? Biddulphii | XI. 8. | 626 | .. | .. | .. | * | * | .. | .. | .. |
| 6 | ——— ? Cornu-arietis, *α* | XX. 20. | 643 | .. | .. | .. | .. | .. | * | .. | .. |
| 7 | ——— ——— *β* | XXII. 18. | — | .. | .. | .. | .. | .. | .. | .. | * |
| 1 | Phragmoceras arcuatum | X. 1. | 621 | .. | .. | .. | * | .. | .. | .. | .. |
| 2 | ——— ——— *β* | XI. 1. | — | .. | .. | .. | * | .. | .. | .. | .. |
| 3 | ——— ? nautileum | X. 2 and 3. | 622 | .. | .. | .. | * | .. | .. | .. | .. |
| 4 | ——— ventricosum (Orth. ventricosus *Stein.* ?) | X. 4, 5 and 6. | 621 | .. | .. | .. | * | .. | .. | .. | .. |
| 5 | ——— compressum | XI. 2. | — | .. | .. | .. | * | .. | .. | .. | .. |
| 1 | Cyrtoceras læve | VIII. 21. | — | .. | * | .. | * | .. | .. | .. | .. |
| 1 | Orthoceras semipartitum | III. 9 *a*. | 604 | * | .. | .. | .. | .. | .. | .. | .. |
| 2 | ——— tracheale | III. 9 *b*. | — | * | .. | .. | .. | .. | .. | .. | .. |
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| 5 | ——— articulatum, (see Lituites articulatus) | V. 31. | — | .. | * | .. | * | .. | .. | .. | .. |
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| 7 | ——— gregarium | VIII. 16. | 619 | .. | .. | .. | * | .. | .. | .. | .. |
| 8 | ——— distans ? | VIII. 17. | — | .. | .. | .. | * ? | .. | .. | .. | .. |
| 9 | ——— dimidiatum | VIII. 18. | 620 | .. | .. | .. | * | .. | .. | .. | .. |
| 10 | ——— pyriforme | VIII. 19 & 20. | — | .. | .. | * | * | .. | .. | .. | .. |
| 11 | ——— Ludense | IX. 1 *a*. | 619 | .. | .. | .. | * | .. | .. | .. | .. |
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| 14 | ——— filosum | IX. 3. | — | .. | .. | .. | * | .. | .. | .. | .. |
| 15 | ——— virgatum | IX. 4. | — | .. | * | * | * | .. | * | .. | .. |
| 16 | ——— annulatum, *M. C.* (O. undulatus, *His.*) | IX. 5. | 632 | .. | .. | .. | * | * | * | * | .. |
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| 22 | ——— canaliculicatum | XIII. 26. | — | .. | .. | .. | * | * | .. | .. | .. |
| 23 | ——— conicum | XXI. 21. | 642 | .. | .. | .. | .. | .. | .. | * | .. |
| 24 | ——— approximatum | XXI. 22. | — | .. | .. | .. | .. | .. | .. | * | .. |
| 25 | ——— bisiphonatum | XXI. 23. | — | .. | .. | .. | .. | .. | .. | * | .. |
| 26 | ——— trochlearis, *His.?* | not figured. | | .. | .. | .. | .. | * | .. | .. | .. |
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| 3 | ——— conica | III. 7 *b* & 8. | 604 | * | .. | .. | .. | .. | .. | .. | .. |
| 4 | ——— cancellata | XX. 18. | 642 | .. | .. | .. | .. | .. | .. | * | .. |
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| 1 | Turbo Williamsii | III. 6. | 603 | * | .. | .. | .. | .. | .. | .. | .. |
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| 3 | ——— carinatus | V. 28. | — | .. | * | * | .. | .. | .. | .. | .. |
| 4 | ——— cirrhosus | XIII. 22. | 631 | .. | .. | .. | * | .. | .. | .. | .. |
| 5 | ——— Pryceæ | XXI. 19. | 642 | .. | .. | .. | .. | .. | .. | * | .. |
| 1 | Trochus helicites | III. 1 *e* & 5. | 603 | * | * | .. | .. | .. | .. | .. | .. |
| 2 | ——— ? lenticularis | XIX. 11. | 642 | .. | .. | .. | .. | .. | .. | * | .. |
| 1 | Pleurotomaria undata | VIII. 13. | 619 | .. | .. | .. | * | .. | .. | .. | .. |
| 2 | ——— Lloydii | VIII. 14. | — | .. | .. | .. | * | .. | .. | .. | .. |
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| 2 | ——— sculptus | XII. 17. | 626 | .. | .. | * | * | * | .. | .. | .. |
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| 4 | ——— rugosus, *M. C.* | XII. 19. | — | .. | .. | .. | .. | * | .. | .. | .. |
| 5 | ——— funatus, *M. C.* | XII. 20. | — | .. | .. | * | * | * | * | * | .. |
| 6 | ——— alatus | XIII. 28. | 631 | .. | .. | .. | .. | .. | * | .. | .. |
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| 2 | ——— parva | V. 24. | 612 | .. | * | * | * | .. | .. | .. | .. |

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| 2 | ——— ? Haliotis | XII. 16. | — | .. | .. | * | .. | * | .. | | .. | .. |
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| 1 | Patella ? implicata | XII. 14 *a.* | 625 | .. | .. | .. | .. | * | .. | | .. | .. |
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| 2 | ——— minima | V. 23. | 612 | .. | * | .. | .. | .. | .. | | .. | .. |
| 3 | ——— Lewisii | VI. 9. | 615 | .. | .. | * | .. | .. | .. | | .. | .. |
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| 6 | ——— ? striata | VIII. 12. | 619 | .. | .. | .. | * | .. | .. | | .. | .. |
| 7 | ——— attenuata | XXII. 13. | 641 | .. | .. | .. | .. | .. | .. | | .. | * |
| 1 | Pentamerus Knightii, *M. C.* | VI. 8. | 615 | .. | .. | * | .. | * | .. | | .. | .. |
| 2 | ——— lævis, *M. C.* | XIX. 9. | 641 | .. | .. | .. | .. | .. | .. | | * | .. |
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| 3 | ——— lacunosa, (T. borealis, *V. Buch.*) | V. 19. XII. 10. | — | .. | * | .. | * | * | .. | | .. | .. |
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| 9 | ——— imbricata, (T. marginalis, *Dalm.*) | XII. 12. | — | .. | .. | .. | .. | * | * | | .. | .. |
| 10 | ——— ——— var. abbreviata | XIII. 27. | 631 | .. | .. | .. | .. | .. | * | | .. | .. |
| 11 | ——— cuneata, *Dalm.* | XII. 13. | 625 | .. | .. | .. | .. | * | .. | | .. | .. |
| 12 | ——— bidentata, *His.* | XII. 13 *a.* | — | .. | .. | .. | .. | * | .. | | .. | .. |
| 13 | ——— deflexa | XII. 14. | — | .. | .. | .. | .. | * | .. | | .. | .. |
| 14 | ——— læviuscula | XIII. 14. | 631 | .. | .. | .. | .. | .. | * | | .. | .. |
| 15 | ——— brevirostris | XIII. 15. | — | .. | .. | .. | .. | .. | * | | .. | .. |
| 16 | ——— sphærica | XIII. 17. | — | .. | .. | .. | .. | .. | * | | .. | .. |
| 17 | ——— crebricosta | XIII. 18. | — | .. | .. | .. | .. | .. | * | | .. | .. |
| 18 | ——— Stricklandii | XIII. 19. | — | .. | .. | .. | .. | * ? | * | | .. | .. |
| 19 | ——— interplicata | XIII. 23. | — | .. | .. | .. | .. | .. | * | | .. | .. |
| 20 | ——— Unguis | XXI. 13. | 640 | .. | .. | .. | .. | .. | .. | | * | .. |
| 21 | ——— neglecta | XXI. 14. | 641 | .. | .. | .. | .. | .. | .. | | * | .. |
| 22 | ——— tripartita | XXI. 15. | — | .. | .. | .. | .. | .. | .. | | * | .. |
| 23 | ——— furcata | XXI. 16. | 640 | .. | .. | .. | .. | .. | .. | | * | .. |
| 24 | ——— decemplicata | XXI. 17. | 641 | .. | .. | .. | .. | .. | .. | | * | .. |
| 25 | ——— pusilla | XXI. 18. | — | .. | .. | .. | .. | .. | .. | | * | * |
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| 2 | ——— orbicularis | V. 16. | — | .. | * | .. | .. | .. | .. | | .. | .. |
| 3 | ——— rustica | XII. 9. | 624 | .. | .. | .. | .. | * | .. | | .. | .. |
| 4 | ——— hybrida | XIII. 11. | 630 | .. | .. | .. | .. | * | * | | .. | .. |
| 5 | ——— filosa | XIII. 12. | — | .. | .. | .. | .. | * | * | | .. | .. |
| 6 | ——— canalis | XIII. 12 *a.* XX. 8. | — | .. | .. | .. | .. | * | * | | * | * |

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| 7 | Orthis antiquata .................. | XIII. 13. | 630 | .. | .. | .. | .. | .. | * | .. | .. |
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| 11 | ——— testudinaria ................ | XX. 9 and 10. | — | .. | .. | .. | .. | .. | .. | * | * |
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| 13 | ——— grandis ..................... | XX. 12 and 13. | 638 | .. | .. | .. | .. | .. | .. | * | .. |
| 14 | ——— expansa .................... | XX. 14. | — | .. | .. | .. | .. | .. | .. | * | .. |
| 15 | ——— virgata ..................... | XX. 15. | 639 | .. | .. | .. | .. | .. | .. | * | .. |
| 16 | ——— Actoniæ .................... | XX. 16. | — | .. | .. | .. | .. | .. | .. | * | * |
| 17 | ——— triangularis.................. | XX. 17. | 640 | .. | .. | .. | .. | .. | .. | * | .. |
| 18 | ——— semicircularis................ | XXI. 7. | 639 | .. | .. | .. | .. | .. | .. | * | * |
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| 20 | ——— Pecten ? *Dalm.* ............... | XXI. 9. | 638 | .. | .. | .. | .. | .. | .. | * | * |
| 21 | ——— anomala (Anomites anomala, *Schloth.* ............ | XXI. 10. | — | .. | .. | .. | .. | .. | .. | * | * |
| 22 | ——— ? costata..................... | XXI. 11. | 639 | .. | .. | .. | .. | .. | .. | * | .. |
| 23 | ——— protensa .................... | XXII. 8 and 9. | 638 | .. | .. | .. | .. | . | .. | * | * |
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| 25 | ——— radians ..................... | XXII. 11. | 639 | .. | .. | .. | .. | .. | .. | * | .. |
| 26 | ——— compressa .................. | XXII. 12. | 638 | .. | .. | .. | .. | .. | .. | * | *? |
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| 2 | ———trapezoidalis (Cyrtia trapezoidalis, *Dalm. and V. Buch.*) .... | V. 14. | 610 | .. | .. | * | * | * | * | .. | .. |
| 3 | ——— interlineatus................ | VI. 6. | 614 | .. | .. | * | * | .. | .. | .. | .. |
| 4 | ——— radiatus, *M. C.*.............. | XII. 6. | 624 | .. | .. | .. | * | * | * | * | .. |
| | ——————— var................ | XXI. 5. | 638 | .. | .. | .. | .. | .. | .. | * | .. |
| 5 | ——— octoplicatus, *M. C.* .......... | XII. 7. | 624 | .. | .. | .. | .. | * | .. | .. | .. |
| 6 | ——— crispus (Delthyris crispa, *Dalm.*). | XII. 8. | — | .. | * | * | .. | * | * | .. | .. |
| 7 | ——— ? Pisum..................... | XIII. 9. | 630 | .. | .. | .. | .. | .. | * | .. | .. |
| 8 | ——— ? sinuatus (Ter. sinuata, *Sow.* in Linn. Trans.; Delthyris cardiospermiformis, *Dalm.*; Sp. sinuata, *V. Buch.*) ........ | XIII. 10. | — | .. | .. | .. | .. | * | * | .. | .. |
| 9 | ——— (Orthis ?) plicatus .......... | XXI. 6. | 638 | .. | .. | .. | .. | .. | .. | * | * |
| 10 | ——— (Orthis ?) lævis.............. | XXI. 12. | — | .. | .. | .. | .. | .. | .. | * | .. |
| 11 | ——— (Orthis ?) liratus ........... | XXII. 6. | — | .. | .. | .. | .. | .. | .. | * | * |
| 12 | ——— (Orthis ?) alatus ........... | XXII. 7. | — | .. | .. | .. | .. | .. | .. | .. | * |
| 1 | Atrypa didyma (Ter. didyma, *Dalm.*) .. | VI. 4. | 614 | .. | * | * | * | * | .. | .. | .. |
| 2 | ——— affinis (Ter. affinis, *M.C.* and *V. Buch.*; A. reticularis, *Dalm.*; Terebratulites priscus, *Schloth.*) | VI. 5. | — | .. | * | * | * | * | * | * | .. |
| 3 | ——— obovata..................... | VIII. 8 and 9. | 618 | .. | .. | .. | * | * | .. | .. | .. |
| 4 | ——— ? galeata, *Dalm.* ............ | VIII. 10. XII. 4. | — | .. | .. | .. | * | * | * | .. | .. |
| 5 | ——— tenuistriata ................. | XII. 3. | 623 | .. | .. | .. | .. | * | * | .. | .. |
| 6 | ——— aspera, *Dalm.* (Terebr. aspera, *Schloth.*) ................ | XII. 5. | — | .. | .. | .. | .. | * | * | .. | .. |
| 7 | ——— compressa.................. | XIII. 5. | 629 | .. | .. | .. | .. | * | * | .. | .. |
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| 10 | ——— linguifera | XIII. 8. | — | .. | .. | .. | .. | .. | * | * | .. |
| 11 | ——— orbicularis | XIX. 3 and 4. | 637 | .. | .. | .. | .. | .. | * | * | .. |
| 12 | ——— hemisphærica | XX. 7. | — | .. | .. | .. | .. | .. | .. | * | .. |
| 13 | ——— crassa | XXI. 1. | 636 | .. | .. | .. | .. | .. | .. | .. | * |
| 14 | ——— undata | XXI. 2. | 637 | .. | .. | .. | .. | .. | .. | .. | * |
| 15 | ——— Lens | XXI. 3. | — | .. | .. | .. | .. | .. | .. | * | * |
| 16 | ——— ? plana | XXI. 4. | — | .. | .. | .. | .. | .. | .. | * | .. |
| 17 | ——— polygramma | XXI. 4 *a*. | — | .. | .. | .. | .. | .. | .. | * | .. |
| 18 | ——— globosa | XXII. 2 *b*. | — | .. | .. | .. | .. | .. | .. | * | .. |
| 19 | ——— ? | XXII. 3. | — | .. | .. | .. | .. | .. | .. | .. | * |
| 20 | ——— ? | XXII. 4 and 5. | — | .. | .. | .. | .. | .. | .. | .. | * |
| 1 | Leptæna lata, *V. Buch* | III. 10*b*. V. 13. | 610 | * | * | * | .. | .. | .. | .. | .. |
| 2 | ——— Lepisma ? *Dalm.* | VIII. 7. | 618 | .. | .. | .. | * | .. | * | .. | .. |
| 3 | ——— euglypha (Productus euglyphus, *Dalm.*) | XII. 1. | 622 | .. | .. | .. | * | * | * | * | .. |
| 4 | ——— depressa (P. depressa, *M. C. Dalm. and His.*) | XII. 2. | 623 | .. | .. | .. | * | * | * | * | *? |
| 5 | ——— transversalis, *Dalm.* | XIII. 2. | 629 | .. | .. | .. | .. | .. | * | .. | .. |
| 6 | ——— lævigata | XIII. 3. | — | .. | .. | .. | .. | .. | * | .. | .. |
| 7 | ——— minima | XIII. 4 and 4 *a*. | — | .. | .. | .. | .. | .. | * | .. | .. |
| 8 | ——— sericea (striatella ? *Dalm.*) | XIX. 1 and 2 *a*. | 636 | .. | .. | .. | .. | .. | .. | * | * |
| | ——————— var. | XIX. 2. | — | .. | .. | .. | .. | .. | .. | * | .. |
| 9 | ——— complanata | XX. 6. | — | .. | .. | .. | .. | .. | .. | * | .. |
| 10 | ——— tenuistriata | XXII. 2 *a*. | — | .. | .. | .. | .. | .. | .. | * | .. |
| 11 | ——— duplicata | XXII. 2. | — | .. | .. | .. | .. | .. | .. | * | * |
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| 2 | ——— striata | V. 12. | — | .. | * | .. | .. | .. | .. | .. | .. |
| 3 | ——— ? punctata (in the text erroneously O. granulata) | XX. 5. | 636 | .. | .. | .. | .. | .. | .. | * | .. |
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| 1 | Avicula rectangularis | III. 2. | 603 | * | .. | .. | .. | .. | .. | .. | .. |
| 2 | ——— retroflexa ? *His.* | V. 9. | 609 | .. | * | .. | * | .. | .. | .. | .. |
| 3 | ——— lineata | V. 10. | 610 | .. | * | * | .. | .. | .. | .. | .. |
| 4 | ——— reticulata | VI. 3. | 614 | .. | .. | * | * | * | .. | .. | .. |
| 5 | ——— orbicularis | XX. 2. | 635 | .. | .. | .. | .. | .. | .. | * | .. |
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| 6 | ——— obliqua | XX. 4. | — | .. | .. | .. | .. | .. | .. | * | .. |
| | *Ord.* Dimyaria. | | | | | | | | | | |
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| 2 | ——— antiqua | XIII. 1. | 628 | .. | .. | .. | .. | .. | * | .. | .. |
| 1 | Nucula ? ovalis | V. 8. | 609 | .. | * | .. | .. | .. | .. | .. | .. |
| 2 | ——— lævis | XXII. 1. | 635 | .. | .. | .. | .. | .. | .. | .. | * |
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| 3 | ——— ovata | III. 12 *b*. | — | * | .. | .. | .. | .. | .. | .. | .. |
| 1 | Cardiola fibrosa | VIII. 4. | 617 | .. | .. | * | * | .. | .. | .. | .. |

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| 2 | Cardiola interrupta (Cardium ? Cornucopiæ, *Goldf.*) ........ | VIII. 5. | 617 | .. | .. | * | * | .. | .. | .. | .. |
| 1 | Cardium striatum .................. | VI. 2. | 614 | .. | .. | * | * | .. | .. | .. | .. |
| | ——————— var. ............. | ............ | — | .. | .. | * | .. | .. | .. | .. | .. |
| 1 | Pullastra lævis ..................... | III. 1 *a.* | 602 | * | .. | .. | .. | .. | .. | .. | .. |
| 2 | ——— complanata ................ | V. 7. | 609 | .. | * | .. | .. | .. | .. | .. | .. |
| 1 | Psammobia rigida ................... | VIII. 3. | 617 | .. | .. | .. | * | .. | .. | .. | .. |
| 1 | Cypricardia ? cymbæformis (Cardites carpomorphus ? *Dalm.*).. | III. 10 *a.* | 602 | * | * | .. | .. | .. | .. | .. | .. |
| | ——————————— var. .... | V. 6. | 609 | .. | * | .. | .. | .. | .. | .. | .. |
| 2 | ——————? amygdalina............ | V. 2. | — | .. | * | .. | .. | .. | .. | .. | .. |
| 3 | ——————? impressa.............. | V. 3. | — | .. | * | .. | .. | .. | .. | .. | .. |
| 4 | ——————? undata .............. | V. 4. | — | .. | * | .. | * | .. | .. | .. | .. |
| 5 | ——————? retusa................. | V. 5. | — | .. | * | *? | * | .. | .. | .. | .. |
| 6 | ——————? solenoides ........... | VIII. 2. | 617 | .. | .. | .. | * | .. | .. | .. | .. |
| 1 | Mya rotundata ...................... | VI. 1. | 613 | .. | .. | * | .. | .. | .. | .. | .. |
| | CRINOIDEA[1]. | | | | | | | | | | |
| 1 | Cyathocrinites tuberculatus, *Mill.* .... | XVIII. 6 and 7. | 671 | .. | .. | .. | .. | * | .. | .. | .. |
| 2 | ——————— goniodactylus ........ | XVII. 1. | — | .. | .. | .. | .. | * | .. | .. | .. |
| 3 | ——————— capillaris ........... | XVII. 2. | — | .. | .. | .. | .. | * | .. | .. | .. |
| 4 | ——————— pyriformis............ | XVII. 6. | 672 | .. | .. | .. | .. | * | .. | .. | .. |
| 5 | ——————— rugosus, *Mill.* ........ | XVIII. 1. | — | .. | .. | .. | .. | * | .. | .. | .. |
| 1 | Marsupiocrinites cælatus ............ | XVIII. 3. | — | .. | .. | .. | .. | * | .. | .. | .. |
| 1 | Hypanthocrinites decorus............ | XVII. 3. | — | .. | .. | .. | .. | * | .. | .. | .. |
| 1 | Actinocrinites moniliformis, *Mill.* .... | XVIII. 4. | 672 | .. | .. | .. | .. | * | .. | .. | .. |
| 2 | —————— simplex .............. | XVIII. 8. | — | .. | .. | .. | .. | * | .. | .. | .. |
| 3 | ——————? arthriticus .......... | XVII. 8. | 674 | .. | .. | .. | .. | * | .. | .. | .. |
| 4 | ——————? expansus ............ | XVII. 9. | — | .. | .. | .. | .. | * | .. | .. | .. |
| 5 | ——————? retiarius ............ | XVII. 7. | — | .. | .. | .. | .. | * | .. | .. | .. |
| 1 | Dimerocrinites decadactylus.......... | XVII. 4. | — | .. | .. | .. | .. | * | .. | .. | .. |
| 2 | ——————— icosidactylus.......... | XVII. 5. | — | .. | .. | .. | .. | * | .. | .. | .. |
| | POLYPARIA. | | | | | | | | | | |
| 1 | Aulopora conglomerata, *Goldf.*......... | XV. 9. | 675 | .. | .. | .. | .. | * | .. | .. | .. |
| 2 | ——— consimilis ................ | XV. 7. | — | .. | .. | .. | .. | * | .. | .. | .. |
| 3 | ——— serpens, *Goldf.* ............ | XV. 5. | — | .. | .. | .. | .. | * | * | *? | .. |
| 4 | ——— tubæformis, *Goldf.*.......... | XV. 8. | 676 | .. | .. | .. | .. | * | .. | .. | .. |
| 1 | Escharina ? angularis .............. | XV. 10. | — | .. | .. | .. | .. | * | .. | .. | .. |
| 1 | Ptilodictya lanceolata .............. | XV. 11. | — | .. | .. | .. | .. | * | .. | .. | .. |
| 1 | Glaucomene disticha, *Goldf.* ........ | XV. 12. | 677 | .. | .. | .. | .. | * | .. | .. | .. |
| 1 | Hornera crassa ..................... | XV. 13. | — | .. | .. | .. | .. | * | .. | .. | .. |
| 1 | Fenestella antiqua.................. | XV. 16. | 678 | .. | .. | .. | .. | * | .. | .. | .. |
| 2 | ——— Milleri .................. | XV. 17. | — | .. | .. | .. | .. | * | .. | .. | .. |

[1] N.B. Columns and plates of Crinoidea occur in all the Silurian formations from the Upper Ludlow Rock to the base of the Llandeilo Flags, Pl. IV, 56, XVIII, 2, 5, and 9, XX, 19, and also in the underlying Cambrian Rocks, but clearly determinable species have as yet been found in the Wenlock Limestone only.—R. I. M.

| Number of species. | Genus and Species. | Description and Figure in this work. Plate and Figure. | Page. | Old Red Sandstone (middle and lower beds only.) | Silurian Rocks. Upper. Upper Ludlow Rock. | Aymestry Limestone. | Lower Ludlow Rock. | Wenlock Limestone. | Wenlock Shale. | Lower. Caradoc Sandstone. | Llandeilo Flags. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 3 | Fenestella prisca | XV. 15, 18. | 678 | .. | .. | .. | .. | * | .. | .. | .. |
| 4 | ———— reticulata | XV. 19. | — | .. | .. | .. | .. | * | .. | .. | .. |
| 1 | Discopora antiqua ? *M. Edw.* | XV. 21. | 679 | .. | .. | .. | .. | * | .. | .. | .. |
| 2 | ———— squamata | XV. 23. | — | .. | .. | .. | .. | * | .. | .. | .. |
| 3 | ———— ? favosa | XV. 22. | — | .. | .. | .. | .. | * | .. | .. | .. |
| 1 | Berenicea irregularis | XV. 20. | — | .. | .. | .. | .. | * | .. | .. | .. |
| 1 | Retepora infundibulum | XV. 24. | — | .. | .. | .. | .. | * | .. | .. | .. |
| 1 | Eschara ? scalpellum | XV. 25. | — | .. | .. | .. | .. | * | .. | .. | .. |
| 1 | Blumenbachium globosum ? *Kön.* | XV. 26. | 680 | .. | .. | .. | .. | * | .. | .. | .. |
| 1 | Gorgonia assimilis | XV. 27. | — | .. | .. | .. | .. | * | .. | .. | .. |
| 2 | ———— ? (not named) | XV. 28. | — | .. | .. | .. | .. | .. | * | .. | .. |
| 1 | Ceriopora granulosa, *Goldf.* | XV. 29. | — | .. | .. | .. | .. | * | .. | .. | .. |
| 1 | Heteropora crassa | XV. 14. | — | .. | .. | .. | .. | .. | .. | .. | .. |
| 1 | Millepora repens, *His.* | XV. 30. | — | .. | .. | .. | .. | * | .. | .. | .. |
| 1 | Stromatopora concentrica, *Goldf.* | XV. 31. | — | .. | .. | .. | .. | * | * | .. | .. |
| 2 | ———— nummulitisimilis | XV. 32. | 681 | .. | .. | .. | .. | * | .. | .. | .. |
| 1 | Alveolites ? fibrosa | XV. 1. | — | .. | * | * | .. | .. | .. | .. | .. |
| 1 | Favosites alveolaris, *De Blainv.* | XV *bis.* 1, 2. | — | .. | .. | * | * | * | * | * | .. |
| 2 | ———— Gothlandica, *Lam.* | XV *bis.* 3, 4. | 682 | .. | .. | * | * | * | * | * | .. |
| 3 | ———— multipora | XV *bis.* 5. | 683 | .. | .. | .. | .. | * | *? | .. | .. |
| 4 | ———— fibrosa, *Goldf.* | XV *bis.* 6, 7. | — | .. | .. | * | * | * | * | * | .. |
| 5 | ———— spongites, *Goldf.* | XV *bis.* 8, 9. | — | .. | .. | .. | .. | * | .. | .. | .. |
| 6 | ———— polymorpha, *Goldf.* | XV. 2. | 684 | .. | * | * | .. | ? | .. | .. | .. |
| 1 | Syringopora reticulata, *Goldf.* | XV *bis.* 10. | — | .. | .. | .. | .. | * | .. | .. | .. |
| 2 | ———— bifurcata | XV *bis.* 11. | 685 | .. | .. | * | .. | * | .. | .. | .. |
| 3 | ———— filiformis ? *Goldf.* | XV *bis.* 12. | — | .. | .. | .. | .. | * | .. | .. | .. |
| 4 | ———— cæspitosa ? *Goldf.* | XV *bis.* 13. | — | .. | .. | .. | .. | * | .. | .. | .. |
| 1 | Catenipora escharoides, *Lam.* | XV *bis.* 14. | — | .. | .. | * | * | * | * | * | * |
| 1 | Porites pyriformis | XVI. 2. | 686 | .. | .. | * | * | * | * | .. | .. |
| 2 | ———— petalliformis | XVI. 4. | 687 | .. | .. | .. | .. | .. | * | .. | .. |
| 3 | ———— tubulata | XVI. 3. | — | .. | .. | .. | .. | * | .. | .. | .. |
| 4 | ———— expatiata | XV. 3. | — | .. | .. | * | .. | * | .. | .. | .. |
| 5 | ———— inordinata | XVI *bis.* 12. | — | .. | .. | .. | .. | .. | .. | .. | * |
| 6 | ———— discoidea | XVI. 1. | 688 | .. | .. | .. | .. | * | .. | .. | .. |
| 1 | Monticularia conferta | XVI. 5. | — | .. | .. | .. | .. | * | .. | .. | .. |
| 1 | Astræa ananas, *De Blainv.* | XVI. 6. | — | .. | .. | .. | .. | * | .. | .. | .. |
| 1 | Caryophyllia flexuosa, *Lam.* | XVI. 7. | 689 | .. | .. | .. | .. | .. | * | .. | .. |
| 1 | Acervularia Baltica, *Schweig.* | XVI. 8. | — | .. | .. | .. | .. | * | .. | .. | .. |
| 1 | Cyathophyllum turbinatum, *Goldf.* | XVI. 11. | 690 | .. | .. | .. | .. | * | * | * | .. |
| 2 | ———— angustum | XVI. 9. | — | .. | .. | .. | .. | .. | * | * | .. |
| 3 | ———— cæspitosum ? *Goldf.* | XVI. 10. | — | .. | .. | .. | .. | * | * | * | .. |
| 4 | ———— dianthus, *Goldf.* | XVI. 12. | — | .. | .. | .. | .. | * | * | * | .. |
| 1 | Cystiphyllum Siluriense | XVI *bis.* 1, 2. | 691 | .. | .. | .. | .. | * | .. | .. | .. |
| 2 | ———— cylindricum | XVI *bis.* 3. | — | .. | .. | .. | .. | * | .. | .. | .. |
| 1 | Strombodes plicatum, *Ehr* | XVI *bis.* 4. | — | .. | .. | .. | .. | * | .. | .. | .. |
| 1 | Cladocora sulcata | XVI *bis.* 9. | 692 | .. | .. | .. | .. | * | .. | .. | .. |
| 1 | Graptolithus Ludensis (Prionotus sagittarius, *His.*) | XXVI. 1, 2. | 694 | .. | .. | .. | * | .. | * | .. | .. |
| 2 | ———— foliaceus | XXVI. 3. | — | .. | .. | .. | .. | .. | .. | .. | * |
| 3 | ———— Murchisonii, *Beck.* | XXVI. 4. | — | .. | .. | .. | .. | .. | .. | * | * |
| 1 | Limaria clathrata, *Stein.* | XVI *bis.* 7. | 692 | .. | .. | .. | .. | * | .. | .. | .. |

| Number of species. | Genus and Species. | Description and Figure in this work. Plate and Figure. | Page. | Old Red Sandstone (middle and lower beds only.) | Silurian Rocks. Upper. Upper Ludlow Rock. | Aymestry Limestone. | Lower Ludlow Rock. | Wenlock Limestone. | Wenlock Shale. | Lower. Caradoc Sandstone. | Llandeilo Flags. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | Limaria fruticosa, *Stein.* | XVI *bis.* 8. | 692 | .. | .. | .. | .. | * | * | .. | .. |
| 1 | Turbinolopsis bina | XVI *bis.* 5. | — | .. | .. | * | * | * | * | * | .. |
| 2 | ———— ? | XVI *bis.* 6. | 693 | .. | .. | .. | .. | .. | .. | * | .. |
| 1 | Cyclolites lenticulata | XV. 5. | — | .. | .. | * | * | .. | .. | .. | .. |
| 2 | ———— præacuta (C. numismalis, *His.*). | XV. 4. | — | .. | .. | * | * | .. | .. | .. | .. |
| 1 | Verticillipora ? abnormis | XVI *bis.* 10. | — | .. | .. | .. | .. | * ? | .. | .. | .. |
| 1 | Cnemidium tenue | XVI *bis.* 11. | 694 | .. | .. | .. | .. | * | .. | .. | .. |
| | **SEDIS INCERTÆ.** | | | | | | | | | | |
| 1 | Tentaculites tenuis | V. 33. | 613 | .. | .. | .. | * | .. | .. | .. | .. |
| 2 | ———— ornatus | XII. 25. | 628 | .. | .. | .. | .. | * | .. | .. | .. |
| 3 | ———— scalaris, *Schloth.* | XIX. 15. | 643 | .. | * ? | .. | .. | .. | .. | * | .. |
| 4 | ———— annulatus, *Schloth.* | XIX. 16. | — | .. | .. | .. | .. | .. | .. | * | .. |
| 1 | Cornulites serpularius, *Schloth.* | XXVI. 5 to 9. | 627 | .. | .. | .. | .. | * | .. | .. | .. |
| 1 | Ischadites Königii | XXVI. 11. | 697 | .. | .. | .. | * | .. | .. | .. | .. |
| 1 | Cophinus dubius | XXVI. 12. | 697 | .. | * | .. | .. | .. | .. | .. | .. |
| 1 | Spongarium Edwardsii | XXVI. 10. | 696 | .. | * | .. | .. | .. | .. | .. | .. |
| 1 | Polymeres Demetarum | XXVI. 13. | 698 | .. | .. | .. | .. | .. | .. | .. | * |
| | Besides the above-mentioned Organic Remains of the old Red Sandstone and Silurian System, certain convoluted bodies in the Cambrian Rocks are described by Mr. W. MacLeay as *Annelida* (p. 698.), the specific names being assigned by myself. They are | | | | | | | | | | |
| 1 | Nereites Cambrensis | XXVII. 1. | 700 | .. | .. | .. | .. | .. | .. | .. | .. |
| 2 | ———— Sedgwickii | XXVII. 2. | — | .. | .. | .. | .. | .. | .. | .. | .. |
| 1 | Myrianites MacLeayii[1] | XXVII. 3. | — | .. | .. | .. | .. | .. | .. | .. | .. |
| 1 | Nemertites Ollivantii | XXVII. 4. | 701 | .. | .. | .. | .. | .. | .. | .. | .. |

## RECAPITULATION.

| | No. of Genera. | No. of Species. |
|---|---|---|
| Pisces | 15 | 24 |
| Crustacea | 10 | 37 |
| Annelida | 5 | 6 |
| Mollusca (ord. Heteropoda) | 1 | 11 |
| ———— (ord. Cephalopoda) | 6 | 41 |
| ———— (ord. Gasteropoda) | 13 | 34 |
| Conchifera (ord. Brachiopoda) | 8 | 107 |
| ———— (ord. Monomyaria) | 1 | 6 |
| ———— (ord. Dimyaria) | 10 | 21 |
| Crinoidea | 5 | 14 |
| Polyparia | 35 | 65 |
| Sedis incertæ | 6 | 9 |
| Total | 115 | 375 |

## DESCRIPTION OF THE SECTIONS.

### *PLATE* 29[1] *TO* 37.

### PLATE 29.

Fig. 1. From the Cotteswold Hill near Cheltenham on the east, to Haffield Camp near Ledbury, Herefordshire, on the west; showing a conformable succession of all the formations, from the Inferior Oolite to the base of the New Red System. The subdivisions of the lias and of the upper portion of the New Red System (including the Keuper Sandstone), are the chief objects. The Lower New Red Sandstone, properly so called, is not developed; the New Red System being terminated by a conglomerate partially filled with syenite. The Old Red Sandstone in unconformable strata, rises from beneath the New Red conglomerate. See p. 14 *et seq.*

Fig. 2. From the Hawkston Hills, Shropshire, to the Peckforton Hills, Cheshire; indicating the position of a basin of lias around Prees and Cloverly. See p. 22 *et seq.*

Fig. 3. From Lyth Hill near Shrewsbury, to Prees; explaining the succession of strata from the coal-measures to the lias, including the subdivisions of the New Red System. The coal-measures passing upwards into the Lower New Red Sandstone, constitute the newest member of the Carboniferous System, contain fresh-water limestone, are highly dislocated, and repose upon the Cambrian Rocks. See p. 39.

Fig. 4. Shows a peculiar conglomerate at the base of the New Red Sandstone, (Rosemary Rock, Worcester). The Lower Silurian Rocks of Ankerdine Hill are in unconformable contact. See pp. 53, 415.

Fig. 5. Lower New Red Sandstone and Upper Coal-measures at Wellbatch, near Shrewsbury, resting on Cambrian Rocks as in f. 3. See pp. 93 *et seq.*

Fig. 6. Upper coal and fresh-water limestone at Uffington, near Shrewsbury, resting unconformably on Cambrian Rocks as in figs. 3 and 5. See pp. 81, 92.

Fig. 7. Upper coal and freshwater limestone at Pontesbury, passing under Lower New Red Sandstone and calcareous conglomerate, and resting upon the quartz rock of the Stiper stones. See pp. 81, 83 *et seq.*

Fig. 8. Section of the upper coal and limestone strata, as seen near Pontesbury where affected by a fault. The details of the Shrewsbury coal seams, and their relations to the included limestone, are here expressed on a larger scale than in the other sections. See p. 90.

Fig. 9. Upper coal-measures of the Shrewsbury field, resting upon Silurian Rocks at Bauseley and Bragginton, showing further how the same coal-measures pass under the Lower New Red Sandstone of Pecknall near Alberbury, the whole surmounted by calcareous conglomerate, the equivalent of the Magnesian Limestone or Dolomitic Conglomerate. See pp. 29, 82.

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[1] There is no Pl. 28. in this work, the subject of Pl. 27. being that which terminates the illustration of the Organic Remains and immediately precedes Pl. 29. This was caused by the desire to place the folding plates of sections after the single plates of the Organic Remains; the former having been numbered at an early period, in order to pass the work through the press.

Fig. 10. From the south end of the Dudley coal-field across the Clent Hills, to prove that the coal-measures pass upwards into the Lower New Red Sandstone in Worcestershire, as well as in Shropshire, the last-mentioned formation being overlaid in both counties, by calcareous conglomerates. N.B. The thick or 10 yard coal of Dudley is lost by a fault, and has not yet been proved beneath the Lower New Red, though there is little doubt of its existence. See pp. 47, 506, and Pl. 37, figs. 1 and 6.

Fig. 11. From Apley Terrace on the S.E., to Wrockardine on the N.W., traversing in descending order. 1st. Lower New Red Sandstone. 2nd. The coal and ironstone measures of Coal Brook Dale. 3rd. Carboniferous Limestone; the whole resting unconformably on various members of the Silurian System. Some trap rocks (greeestone, basalt, &c.), penetrate the coal-field, and other trap rocks (syenite and felspar rock), pierce the Lower Silurian Rocks at the Wrekin, &c.
The Caradoc Sandstone in contact with the Wrekin trap, is converted into quartz rock. See pp. 61, 103.

Fig. 12. From Apley on the E.N.E., to Tasley, near Bridgenorth on the W.S.W.; exposing a full development of the Lower New Red Sandstone and its passage downwards, into the upper coal with freshwater limestone. See pp. 61, 100.

Fig. 13. From Wolverhampton on the east, to Bagley Rough and the Severn on the west; exhibiting a trough of New Red Sandstone between the coal-fields of Staffordshire and Coalbrook Dale. Many granitic and other boulders of northern origin encumber the surface of this tract. The oblique face of the fault at Wolverhampton is specially worthy of remark. See pp. 41, 61, 503.

Fig. 14. Anticlinal of the Carboniferous Limestone of Lilleshall, in the direction of the chief trappean eruptions of the adjacent coal-field, and parallel to the strike of the Silurian Rocks.

Fig. 15. From Lilleshall House (the new mansion of the Duke of Sutherland) on the east, to the village and hill of Lilleshall on the west, pointing out a succession from the calcareous (dolomitic) conglomerate of the New Red Sandstone, through the Lower New Red Sandstone, down to the coal-measures and Carboniferous Limestone. The syenitic trap of Lilleshall Hill, penetrates the Lower Silurian Rocks, as at the Wrekin. See pp. 48, 235.

Fig. 16. From Ketley on the east, to Ercal Hill on the west; showing how the Carboniferous Limestone supports the coal-measures. The coal-measures are much penetrated by trap, and have been affected by powerful faults, the lower coal having been thrown up nearly to the surface in the centre of the field. On the sides of Ercal Hill the Caradoc Sandstone is converted into quartz rock. See pp. 103, 110, 233.

Fig. 17. Section across the Broseley district of the Coal Brook Dale field; showing, as in f. 16., how the coal-measures have been upheaved through the Lower New Red Sandstone, and how they are eventually cut out by the rise of the Silurian Rocks (Wenlock Limestone, &c.), and various bosses of trap. The phenomenon of altered sandstone on the sides of the Wrekin, is again exhibited. The faults in this and the preceding figure are inserted by his permission from drawings of Mr. Prestwich. See pp. 110, 233.

## PLATE 30.

Fig. 1. Section from the Titterstone Clee Hill on the south-west, to the banks of the Severn on the north-east, exhibiting a central axis of Old Red Sandstone. On the south-western side of this axis, the ascending series of strata is unbroken, from the Carboniferous Limestone of Oreton

to the productive coal-field, through a large development of Millstone Grit. To the north-east the section passes, first across the trap and broken coal-measures of Kinlet, and thence through a poor coal-field, which as it approaches the banks of the Severn, sinks conformably beneath the Lower New Red Sandstone of Chelmarsh, Higley, Alveley, &c. See pp. 60, 113, 117, 121, 131.

Fig. 2. Section at Bewdley, to show the unconformable relations of New Red Sandstone to the carboniferous grits of the Forest of Wyre. See pp. 54, 134.

Fig. 3. From the hills north of Shatterford to Kidderminster, showing a central, elevated trough of Old Red Sandstone with cornstone. A dyke of trap appears at Shatterford, throwing off the coal upon its eastern flank. Lower New Red Sandstone overlies the coal conformably on the north, whilst other and superior members of the New Red System, flank and dip away from the Old Red Sandstone to the south, in *un*conformable positions. See pp. 54, 137, 178.

Fig. 4. Repetition of the phenomena seen at the eastern end of f. 1., showing passage of coal-measures into Lower New Red Sandstone, with courses of impure limestone (Borle Brook.). See p. 60.

Fig. 5. Faults producing a conical mass of Carboniferous Limestone at the escarpment south of the Cornbrook coal-field of the Clee Hills. See p. 120.

Fig. 6. General Section across the Clee Hills, showing on the south an ascending series from the Old Red Sandstone with cornstone, through the Carboniferous Limestone and Millstone grit, to the productive coal-field. Basalt rises through the centre of these hills, capping the coal of Cornbrook and the Old Red Sandstone of Titterstone Clee. In the Brown Clee Hills the Old Red Sandstone (with zones of Cornstone), supports the coal-measures without the intervention of Carboniferous Limestone; the Millstone grit or "hill rock" being alone interposed. The Old Red Sandstone is thrown up between the Clee Barf and Abdon Barf. The minor faults in the Clee Barf are not given, but those of Abdon Barf being upcasts towards the basaltic summit, are noticed.

Fig. 7. Section across the Knowlbury coal-basin (Titterstone Clee Hill), showing the dislocations by which it has been thrown into the form of a basin. The sudden expansion of the coal between certain faults is a remarkable phenomenon. See pp. 114, 117.

Fig. 8. The relations of the coal and basalt at the Hoar Edge, (Titterstone Clee), and a cone of trap with dislocated coal-measures discovered in sinking a trial shaft. See pp. 113, 128.

Fig. 9. Relations of Coal-measures and Lower New Red Sandstone on the banks of the Severn, at Higley and Stanley, showing an upcast fault of the former near the river, and a further elevation of Old Red Sandstone on the west. (N.B. The Higley grindstone in the Lower New Red was formerly supposed to be Old Red Sandstone.) See pp. 133.

Fig. 10. Showing a thin zone of coal-measures north of Newent, interposed between the Old and New Red Sandstone. See p. 153.

Fig. 11. Great upcast of Old Red Sandstone in Fan-sir-gaer (Caermarthen-fans), to 800 feet above its level in the adjacent hill of Carreg-ogof. The line of fault runs nearly from north to south. See p. 165, and Map.

Fig. 12. Repetition of upcast similar to phenomena in f. 11., but to a less extent; the Carboniferous Limestone not being removed on the side elevated. See pp. 157, 165.

Fig. 13. Fault in the Old Red Sandstone near Lydney, Gloucestershire.

Fig. 14. General section across the Oswestry coal-field, from the Lower New Red Sandstone of the plains of Shropshire, to the mountains of Lower Silurian Rocks near Llansylin. The faults

affecting the Oswestry coal increase in intensity on the rise. The coal is seen to be worked in recent shafts through the Lower New Red Sandstone. The Millstone grit and Carboniferous Limestone are largely developed, but the Old Red Sandstone and younger Silurian Rocks are wanting. See pp. 64, 141 *et seq.*

## PLATE 31.

Fig. 1. From the Millstone Grit and Carboniferous Limestone, forming the edge of the South Welch coal basin near Abergavenny, to the Upper Silurian Rocks of Radnorshire, which constitute the Begwm and Pains Castle hills on the left bank of the Wye. In this section the vale of the Usk has been the scene of a powerful dislocation, to the north-west or upcast side of which is the remarkable and lofty outlier of Carboniferous Limestone "Pen-cerrig-calch" (borders of the Black Forest). This section is chiefly designed to exhibit the enormous development of the Old Red System in this part of England (Herefordshire), and its subdivision into 1. Conglomerate and sandstones. 2. Cornstones, marls and sandstone. 3. Tilestone, &c. Although this section traverses a contortion of the Ludlow Rocks, near their junction with the Old Red Sandstone, (the line of the Ludlow and Brecon anticlinal), the prevalent arrangement along the Begwn and Clyro Hills, exhibits a *perfectly conformable* passage from the one system into the other. See Map and pp. 156, 163, 171, 176 *et seq.*, 336 *et seq.*

Fig. 2. Section of the Upper Silurian Rocks as they appear in the neighbourhood of Ludlow, explaining the subdivisions of the Ludlow and Wenlock formations on a larger scale than in the other figures. See pp. 196 *et seq.*

Fig. 3. From the coal-field of the Titterstone Clee Hills to the Cambrian Rocks of the Longmynd, exhibiting a succession of the Ludlow and Wenlock formations rising from beneath the Old Red Sandstone and underlaid by the Caradoc Sandstone, the latter being fully developed on the banks of the Onny, though in hills of low altitude. The volcanic axis of Caer Caradoc breaks in upon the sequence of the Lower Silurian Rocks and no Llandeilo Flags are visible. See pp. 124, 174, 179, 196, 216 *et seq.*, 256 *et seq.*

Fig. 4. From the coal measures and basalt of the Brown Clee Hills to the quartz rock of the "Stiper Stones" (north-eastern end of the mining tract of Shelve); passing over the same succession of Old Red Sandstone and Silurian Rocks as in f. 3., with examples of the conversion of Caradoc sandstone into quartz rock by the outburst of volcanic matter. (Caer Caradoc.) Trap is seen protruding at many points through the Cambrian Rocks, and copper and lead ores occur occasionally near the contact. A remarkable outlier of Ludlow Rocks is seen at Botville, near Church Stretton, in a vertical position on the north-western face of the trap of Caer Caradoc. See pp. 122, 174, 196, 216, 220, 231 *et seq.*

Fig. 5. Section across the Ludlow promontory, exposing in its centre the valley of elevation of Wigmore Lake. A double upcast is seen to the south-east and a single upcast to the north-west, the descending series from each flank being Old Red Sandstone, Ludlow Rocks, Wenlock Limestone, and Shale, the latter occupying the centre of the denudation. This is a striking point of the great Ludlow and Brecon anticlinal which is traceable by Old Radnor, and the Wye at Erwood, and reappears to the south-west near Brecon. See Map and pp. 196 *et seq.*, 238.

Fig. 6. Traverse from five miles north of Brecon to the hills of Llwyn Madoc passing over the "Brecon anticlinal," a ridge composed of Ludlow Rocks which at Castel Madoc are thrown

into a double flexure and dip beneath the Old Red Sandstone of Mynidd Epynt and Brecon. A complete section of the Upper Silurian Rocks is exposed in descending the escarpment of that tract to the vale of the Irthon (Cwm-craig-dhu).

The Brecon anticlinal is the continuation of that of Ludlow explained in f. 5. See Map and pp. 336 *et seq.*

Fig. 7. Traverse of the same "Brecon anticlinal," as in f. 6., where it has diminished to a single ridge, having a powerful fault on its north-western face. See pp. 338 *et seq.*

Fig. 8. Traverse of the same anticlinal where still more diminished, one mile from its termination. The fault here is on the south-eastern face. See p. 338.

Fig. 9. Traverse of the same anticlinal at Corn-y-fan, where it terminates in a single rock flanked by Old Red Sandstone, which is violently dislocated on the south-eastern face. See p. 337.

## PLATE 32.

Fig. 1. From the Caradoc, on the E.S.E., to the valley of the Severn in the W.N.W., across the Cambrian Rocks of the Longmynd or great mineral axis of west Salop into the adjoining parts of Montgomeryshire. The Silurian System lies to the south-east, as expressed in Pl. 31. figs. 3 and 4. On the north-western flank of the Longmynd and Linley Hills appears the striking ridge of quartz rock called the "Stiper Stones," succeeded by the dislocated and mineralized region of Shelve and Cornden, where the Lower Silurian rocks (Caradoc and Llandeilo) undulate conformably with bedded trap rocks, and are also pierced by intrusive masses of trap. A trough of Upper Silurian Rocks is exposed towards the vale of the Severn, with a cone of intrusive trap and altered rocks at Nant-cribba. The most productive lead veins lie between the Stiper Stones and the Cornden, and occur exclusively in the *stratified deposits* near the intrusive trap rocks. See pp. 223, 256 *et seq.*, 268 *et seq.*, 300 *et seq.*

Fig. 2. A second traverse across the same mining district in another parallel, showing still more clearly the distinction between the bedded trap, formed contemporaneously with the Lower Silurian strata and the intrusive trap which has pierced and altered them. The great trough of unaltered Upper Silurian Rocks on the W.N.W. is well exhibited in the Long Mountain. At the western extremity of the section, the trap dyke of Welch Pool penetrates beds of Caradoc sandstone and impure limestone. See pp. 223, 268 *et seq.*

Fig. 3. A third traverse of the same mineral tract further to the S.S.W.; to show that the anticlinal and synclinal lines of Nos. 1 and 2 are not continuous to any great distance, but change with each short outburst of intrusive trap rock. See pp. 268 *et seq.*

Fig. 4. Unconformable relations of the Upper Limestone of the Caradoc formation to the Cambrian rocks of Linley; also showing veins of copper ore running through the strata of *both systems.* See p. 258.

Fig. 5. Transverse section of the Breidden Hills, marking their eruptive character, the Silurian schist and sandstone on their flanks being much dislocated and altered. See pp. 587 *et seq.*

Fig. 6. On the south-eastern flank of the Breidden Hills, near Middleton, proving that the stratified masses contiguous to points of eruptive trap are penetrated by mineral veins: a repetition of evidence similar to that which is offered in figs. 1, 2 and 3. See pp. 587 *et seq.*

Fig. 7. General relations of the Breidden Hills to the country on their flanks at their north-eastern extremity. Stratified trap alternates with Lower Silurian schist and sandstone (Bauseley Hill) in vertical beds, while intrusive trap appears in Brimford Wood. The coal-field of Bragginton

and Coed Way (full of faults) rests on the edges of the Silurian rocks and passes conformably under the Lower New Red Sandstone and Dolomitic Conglomerate of Pecknall and Alberbury. See pp. 587 *et seq.*

Fig. 8. Alteration and dislocation of the New Red Sandstone, as seen at Pim Hill, upon the line of the eruptive axis of the Breidden Hills. This spot is between the great outburst of trappean matter and the dykes composed of the same at Acton Reynolds. (See Map for the extension of this line of dislocation into Staffordshire.) See pp. 587 *et seq.*

Fig. 9. General section from the Long Mountain across the Vales of the Severn, Ffirnwy and Tannat, to the south-eastern flanks of the Berwyn mountains, near Llanrhaidr, explaining how the strata of the Silurian System are extended by a number of undulations over so wide an area.

In proceeding from the south-east, the Caradoc sandstone and its impure limestone are seen to rise from beneath the Upper Silurian Rocks at Powis Castle. Troughs of Upper Silurian rocks (mudstone) succeed. The Caradoc Sandstone re-appears upon the left bank of the Fyrnwy (Allt-y-maen) and is continued by rapid undulations to the vale of the Tannat. The Llandeilo Flags with *Asaphus Buchii, Encrinites* and other fossils, and forming the *base of the Silurian System,* rise from beneath the Caradoc formation and pass down into the slaty Cambrian schists of the Berwyns.

This section, so important in the verification of the order of succession, may be considered the prolongation of figs. 1 and 2. The north-western part of it, including all the tract between the Ffyrnwy and the Berwyns, was inserted by Professor Sedgwick, in company with whom the author first examined that district. See pp. 300, 306 *et seq.*

## PLATE 33.

Fig. 1. From the Longmynd on the north-east, to the hills on the right bank of the Ithon, near Llanbadarn fynidd, exposing a vast trough of Upper Silurian rocks and Old Red Sandstone; the Silurian rocks resting unconformably at either end upon Cambrian rocks, the connecting Lower Silurian strata being wanting. The great outlier of Old Red Sandstone which occupies Clun Forest, exhibits on most sides conformable passages into the Ludlow Rock. See pp. 258, 300, 311 *et seq.*

Fig. 2. From the south-east of Kington to the north-west of Nash Scar near Presteign; showing a regular succession through the Ludlow formation, as it appears in Herrock Hill, to the Wenlock Limestone and Caradoc Sandstone. These formations being upon a line of volcanic eruption, the limestone is for the most part unstratified and crystalline, and the sandstone is heaved up in a mural form with an outlier of Old Red Sandstone on the north-west. Another line of dislocation is seen at Kington, near the junction of the Old Red Sandstone and Upper Ludlow Rock. See pp. 311 *et seq.*

Fig. 3. Traverse of the trappean hills (chiefly Hypersthene Rock and greenstone) of Stanner and Old Radnor, showing how their eruption has dislocated and altered the Ludlow and Wenlock formations. (Thin veins of lead ore appear on the sides of the trap of Old Radnor.) See p. 318.

Fig. 4. From the Old Red Sandstone on the right bank of the Arrow near Kington, across the hills of Hanter and Old Radnor, exhibiting the trap bursting through the Ludlow and Wenlock formations, with slight traces of the Caradoc sandstone; all the strata being highly dislocated, and in parts much altered. Passing to the W.N.W., the section exposes the denudation of the vale of Radnor, and a fine development of Upper Silurian rocks (chiefly the Ludlow formation) in the mountains of Radnor Forest. See pp. 318 *et seq.*

Fig. 5. Traverse across the trappean or volcanized district of Llandrindod and Gelli, to the Cambrian rocks on the west; showing thin-bedded and contemporaneous beds of trap, repeatedly alternating with Lower Silurian rocks (Caradoc and Llandeilo), and rugged knolls of intrusive trap bursting through all the stratified masses and throwing them into anticlinal and synclinal forms. The mineral waters of Llandrindod issue from pyritous and altered shale in contact with the trap. See pp. 324 *et seq.*

Fig. 6. Across the Llandegley rocks (same district as No. 5.) indicating repeated alternation of bedded trap and Caradoc sandstone. Bosses of unstratified greenstone appear near Llandegley village, and the mineral waters of that place issue from the pyritous and altered strata. See pp. 324 *et seq.*

Fig. 7. Great transverse section exposed on the banks of the Wye between the hills of Old Red Sandstone on the south-east to the slaty Cambrian rocks of Rhaydr on the north-west. Strong ridges of Upper Silurian rocks are exposed, together with a small dislocated tongue of Old Red Sandstone, the north-eastern extremity of the great expanse of that system in Mynidd epynt. Lower Silurian rocks are thrown up on the sides of the eruptive trap of Carneddau near Builth (the southern termination of the chain traversed in figs. 5 and 6.); while Upper Silurian Rocks, chiefly their lower members, are repeated in a trough between the Carneddau and the Cambrian rocks of Dol-fan. The Cambrian rocks appear in great undulating masses, chiefly dipping to the north-west, and are in most parts affected by slaty cleavage. The mineral waters of the Park Wells, near Builth, like those of Llandrindod and Llandegley, issue from dislocated and altered strata in contact with trap. See pp. 317, 224 *et seq.*

## PLATE 34.

(Caermarthenshire.) See pp. 347 to 369.

Fig. 1. From the Cwm dwr near Trecastle, to Llandovery, showing a passage from the tilestones of the Old Red Sandstone into the Upper Silurian Rocks, and great undulations between the Upper and Lower Silurian Rocks. The subdivisions of the Silurian System are better seen in figs. 3 and 5. See pp. 347 *et seq.*

Fig. 2. From the left bank of the Towy, south of Llandovery, to the vale of Dole-cothi, being a traverse across part of the Cambrian rocks exposed by the new road to Llampeter, showing large concretions of quartzose grit, which mark the bedding and undulation of imperfect slates which are affected at intervals by oblique cleavage lines. The position of the veins of quartz and pyrites excavated by the Romans at Gogofau is indicated. (N.B. This section should have been placed to the left hand of f. 1. to complete the descending series.) See pp. 347, 360.

Fig. 3. From the junction of the Old Red Sandstone and Upper Silurian Rocks in the escarpment of Mynydd bwlch-y-groes (a continuation of Mynydd epynt) to the hills of Cerrig-gwynion, where the Lower Silurian Rocks pass into the slaty schists of the Cambrian System. In this section the Caradoc Sandstone is well exposed in bold flexures and occupies the hills of Noeth-grüg, the Llandeilo flags occupying the space between Cefn-y-garreg and Cerrig-gwynion. The strata are affected by an oblique slaty cleavage. See pp. 352 *et seq.*

Fig. 4. Cambrian rocks of Cerrig-mwyn and Nant-y-moen, containing productive veins of lead ore. See p. 366.

Fig. 5. From the Millstone Grit and Carboniferous Limestone of the South Welch coal basin to the Towy at Llangadock, showing conformable passages from the Carboniferous System into

the Old Red Sandstone, and from the latter into the Upper Silurian Rocks. The greater part of this section is exposed on the banks of the river Sowdde, which flowing in a rocky channel affords a clear view of the cornstones and tilestones, and the junction of the latter with the equivalent of the Ludlow Rocks (at Pont-ar-lleche, or the bridge upon the tilestones). The trap of Blaen-dyffrin-garn, on the left bank of the Sowdde, penetrates the Lower Silurian Rocks. See pp. 175, 182, 348 and 355.

Fig. 6. From the Millstone Grit and Carboniferous Limestone of the South Welsh coal basin to the banks of the Towy, north of Llandeilo, exposing the relations of the outlier of Carboniferous Limestone called Castell-cerrig-cennen, and the Silurian Rocks in vertical and closely compressed masses.

The Llandeilo Flags are well exposed, and a band of Caradoc Sandstone is interposed between them and the Upper Silurian Rocks.

Fig. 7. From the Millstone Grit and Carboniferous Limestone of the South Welsh coal basin, near the sources of the Lwchor, to the hills north-west of Llandeilo, principally to exhibit a full succession of the Llandeilo flags with stony beds of limestone near the lower limits of that formation (Grüg). See pp. 349 *et seq.*, 355 *et seq.*

Fig. 8. Transverse section from south-east to north-west (similar to figs. 6 and 7.), from Llandibie in the South Welsh coal-field, to the hills of Aberglasslyn on the right bank of the Towy; showing a thin zone of Upper Silurian Rocks rising from beneath the Old Red Sandstone near Golden Grove, and a full extension of the Lower Silurian (principally Llandeilo flags) between that place and Aberglasslyn. To the north-west of Aberglasslyn is a passage downwards from the base of the Llandeilo flags into crinoidal grits, and shale or beds intermediate between the Silurian and Cambrian Systems. (The river Towy flows in a great longitudinal denudation.) See pp. 355 *et seq.*

Fig. 9. From the Millstone Grit and Carboniferous Limestone of Llangyndeyrn to the hills of Cambrian schist, north-west of Caermarthen, showing a small zone of Upper Silurian Rocks, and a peculiar band of Lower Silurian schist on the left bank of the Towy, with fossils of the Llandeilo flags. See p. 358.

Fig. 10. Arch of cornstone in the Old Red Sandstone at Llanstephan Castle, near the mouth of the Towy. See p. 176.

Fig. 11. Traverse from the Old Red Sandstone to the Cambrian schist, a few miles south-west of Caermarthen, showing a line of fault along the junction of the Upper Silurian Rocks with the Old Red, accompanied by outbursts of trap and a peculiar mineral development of the Silurian System. See p. 366.

## PLATE 35.

(Pembrokeshire.) See pp. 370 to 408.

Fig. 1. General transverse section across Pembrokeshire from Pennyholt Stack on the south to Fishguard on the north, exposing the formations in descending order from the Carboniferous Limestone to the slaty rocks of the Cambrian System, with a broken trough of cu.m measures, numerous protrusions of trap, and many dislocations of the strata.

In this section the Silurian Rocks are ill exposed, and in the neighbourhood of Haverfordwest only. The Cambrian Rocks exhibit in one part the peculiar phenomenon of a coincidence between the laminæ of deposit and the lines of slaty cleavage.

Highly altered rocks are seen on the flanks of the trap Trafgarn; and near that of Johnston the Carboniferous Limestone is in an inverted position, appearing to overlie the coal-measures.

Fig. 2. From Milling to Williamston, showing in the northern half of the section a regular descending series of the younger formations, from the productive coal or culm seams, to the Carboniferous Limestone inclusive, and in the southern half the same strata contorted, broken and reversed, with a mass of eruptive trap which pierces the Old Red Sandstone.

Fig. 3. Relations of Lower Coal Measures to Silurian Rocks at Slebech. See p. 372.

Fig. 4. Succession of strata from the north of Narbeth to Amroth, showing the full development and regular order of all the formations from the Silurian System to the culm measures inclusive. See pp. 372, 390.

Fig. 5. Section similar to f. 4. in exhibiting the succession from the Old Red Sandstone to the coal measures, with a full development of the Carboniferous Limestone and Millstone Grit, but differing in showing a break between the Silurian Rocks and the Old Red Sandstone. The upper Silurian Rocks are entirely omitted, while the Llandeilo Flags are very largely expanded near Llampeter-felfrey. See pp. 396 *et seq*.

Fig. 6. Passage from the Old Red Sandstone to the Silurian Rocks near Tavern Spite (Cyffic) in the eastern extremity of Pembrokeshire, with a fine exhibition of the limestone of the Llandeilo Flags at Clog-y-frain, in the adjacent county of Caermarthen.

The River Taaf flows in a gorge formed by the great transverse dislocations of the Lower Silurian Rocks. See pp. 358, 396.

Fig. 7. Coast section of the central portion of St. Bride's Bay, showing the contortions and fractures of the culm measures, and how they rest in some places upon Millstone or Coal Grit, and in others upon Silurian and Cambrian Rocks.

The central or dotted portion represents the lower and unproductive coal grits and sandstones, which are prolonged to Haroldston's Nose from the Poor Field near Haverford-west. See p. 373 *et seq*. 380.

Fig. 8. Relations of the culm beds at Nolton to the Lower Silurian Rocks, showing very little unconformability between them. See pp. 375, 377.

Fig. 9. Relations of culm measures and underlying sandstones and grit to Cambrian Rocks, showing, like f. 8., very little unconformability. At Brawdy, on the contrary, culm rests on Millstone Grit, which is unconformable to the Cambrian Rocks. See map, and pp. 375 *et seq*.

Fig. 10. Great transverse coast section of the Silurian System as exposed in Broad Sound (principally in Marloes Bay) from the Old Red Sandstone on E.S.E. to the Cambrian Rocks on the W.N.W., showing the regular emergence of the Ludlow, Wenlock, Caradoc, and Llandeilo formations. Intrusive trap bursts through the Upper Silurian Rocks (junction of Wenlock and Ludlow) in Marloes Bay; trap rocks, both interstratified and intrusive, alternate with the Cambrian Rocks of Skomer Island and the adjacent promontory. A slaty cleavage prevails throughout the Lower Silurian Rocks, and is partially seen in the upper. See pp. 392 *et seq*.

Fig. 11. Coast section of the Llandeilo Flags, in Musclewick Haven, Marloes; showing their unconformable junction with the Old Red Sandstone. Slaty cleavage traverses these flags obliquely. Faults are marked in the Old Red Sandstone. Eruptive trap overflows the Llandeilo Flags. See p. 394.

## PLATE 36.

(Abberley and Malvern Hills, Valley of Woolhope, May Hill, Tortworth, Usk and Chepstow.)

Figs. 1, 2, 3 & 4 are transverse sections of the Abberley Hills, to show the manner in which the coal measures, Old Red Sandstone, and Silurian Rocks are dislocated and thrown into reversed positions along this axis of trappean elevation.

Fig. 1. Traverse of the Abberley Hills at the Hundred House, showing vertical and disjointed masses of Old Red Sandstone, Ludlow Rocks, and Wenlock Limestone to the west of the axis of trap. To the east is the New Red Sandstone of the Vale of Worcester. To the north-west is the coal of Abberley, being a portion of the carboniferous tract of the Forest of Wyre, the beds of which have the appearance of dipping under the Silurian Rocks. See pp. 135, 409, 420 *et seq.*

Fig. 2. Traverse on the south side of the Tenbury road, to show the trap protruding in a cone, and the Ludlow Rocks in a reversed position, the Old Red Sandstone underlying them and the coal measures in disjointed patches. See pp. 135, 409, 420 *et seq.*

Fig. 3. Traverse across the prominent mass of trap of the Abberley ridge, called Woodbury Hill, still further explaining how the Ludlow Rocks have been placed in an inverted position by the eruption of volcanic matter. Another mass of trap (syenitic greenstone) appears at Brockhill on the Teme, cutting through the Old Red Sandstone. The cornstone formation of the Old Red is well developed on the right bank of the Teme, and an overlying and elevated patch of coal lies on the western flank of Woodbury Hill. See pp. 135, 409, 420 *et seq.*

Fig. 4. Fourth traverse across the Abberley Hills near their southern end (north of Martley), where the trap disappearing from the surface, the Ludlow and Wenlock formations are exposed in a more completely reversed position than in any of the previous sections, namely, at angles of 40° and 45° beyond verticality the Ludlow Rocks distinctly dipping under the Wenlock Limestone, the latter being much fractured. See pp. 409, 421 *et seq.*

Fig. 5. Silurian Rocks occupying the ridge which connects the Abberley and Malvern Hills, consisting of a dome of Caradoc Sandstone in Old Storridge Hill, overlaid conformably by the Wenlock and Ludlow formations, the whole passing beneath the Old Red Sandstone. In this section all these formations have regained their regular positions. To the east the Caradoc Sandstone is flanked unconformably by the New Red Sandstone, the conglomerates of which appear to have been partially upheaved and dislocated. See pp. 52, 415, 422.

Fig. 6. Transverse section of the same ridge, south of f. 5., showing a similar and unbroken ascending succession from the Caradoc Sandstone of Cowley Park to the Old Red Sandstone of Cradley, Herefordshire. A boss of syenite, the northern prolongation of the Malvern Hills, is flanked by Caradoc Sandstone on the west, and impure limestones, probably the upper band of that formation, on the east. See pp. 411, 415.

Fig. 7. Across the syenitic ridge of the Malverns, at North Hill, from the New Red Sandstone of Worcestershire to the Old Red Sandstone of Herefordshire. The Silurian strata in immediate contact with the syenite (near Mathon Lodge), are bent back and reversed, while in receding from the intrusive rock, the beds resume their natural positions. The New Red Sandstone of Great Malvern is partially dislocated on the edge of the syenite, and inclined at 30°. See pp. 52, 183, 411, 415, 423.

Fig. 8. Great transverse section of the Malvern and Ledbury Hills, showing how the outburst of

the syenite has altered and dislocated the strata in contact, and also exposing a regular ascending development of Silurian Rocks, from the base of the Caradoc Sandstone to the Ludlow Rocks inclusive. On the west are great undulations of the Wenlock Limestone, which, rising in domes near Ledbury, is flanked by a thin ridge of Ludlow Rock. As in the previous sections, the Old Red Sandstone lies to the west, the New Red to the east. See pp. 183, 411, 415, 423.

Fig. 9. Transverse section across the valley of Woolhope, showing a regular and unbroken succession in ascending order, on both flanks, from a nucleus of the Caradoc formation through the Upper Silurian Rocks to the Old Red Sandstone.

In this section the only member of the Caradoc formation visible is the impure limestone (on which the village of Woolhope stands) forming the stratum above the sandstone. See pp. 427 *et seq.*

Fig. 9 *b.* Second traverse of the valley of Woolhope near its centre, to show that with a greater amount of elevation, the Caradoc Sandstone, properly so called, is exposed in the culminating point of the central dome (called Haugh Wood), the impure limestone being there denuded, though well exposed on its lower edges. The Wenlock and Ludlow formations are seen in their regular places, but on the western face they are highly inclined and fractured, and the junction with the Old Red Sandstone is obscured by gravel and silt in the denudation of the Wye. See pp. 427 *et seq.*

Fig. 10. This section is merely a repetition of the same phenomena as in f. 9., and was engraved through inadvertence.

Fig. 11. Low dome of Upper Silurian Rocks at Gorstey Common, marking the prolongation of the Woolhope anticlinal. See p. 442.

Fig. 12. From Newent to Aston Ingham, showing how the Woolhope and May Hill anticlinal is marked by upheaved and broken masses of Wenlock Limestone.

The thin and poor coal field of Newent is seen on the east, overlaid by New Red Sandstone. See p. 442.

Fig. 13. Traverse of the same anticlinal at May Hill, from the New Red Sandstone of Huntley to the coal basin of the Forest of Dean, exhibiting a succession in ascending order from the Caradoc Sandstone to the Millstone Grit near Mitchel Dean. See p. 443, 445.

Fig. 14. Section showing the nature of the same axis in a very diminished form at Flaxley, where the May Hill ridge subsides, flanked by the New and Old Red Sandstones. See p. 444.

Fig. 14 *bis.* Arch of Old Red Sandstone near Newnham, marking the continuation of the same anticlinal. See p. 445.

Fig. 15. The same anticlinal, at Haydon Green, south-west of Newnham, marked by an upcast of Ludlow Rock. See p. 445.

Fig. 16. The same anticlinal, as indicated by an arch in the Old Red Sandstone of the Milk-maid Rock, on the right bank of the Severn. See vignette, p. 446.

Fig. 17. The same anticlinal, as it reappears at Purton Passage on the left bank of the Severn, where a low dome of Upper Silurian Rocks throws off the Old Red Sandstone to the south and north, flanked in the latter direction by lias in an unconformable position. See p. 454.

Fig. 18. General transverse section of the Tortworth district, Gloucestershire, from the inferior oolite of the hills above Wotton-under-edge to Aust Cliff on the Severn.

This section shows that the axis of elevation, which is traceable in a single line from Woolhope to Purton Passage, here branches off into two lines, both being marked by the protru-

sion of trap. An elevated basin of Old Red Sandstone is seen to be covered by Carboniferous Limestone with broken and unconformable patches of lias and bands of Dolomitic Conglomerate. The Silurian Rocks are partially seen only in the eastern line of elevation, but are clearly exhibited at Whitfields on the west.

The Old Red Sandstone is overlaid by Dolomitic Conglomerate near Thornbury, and between that place and the Severn by Carboniferous Limestone, New Red Sandstone, and Lias. The "bone beds" or base of the lias cap the low cliffs of Aust, which are composed of red and green gypseous marls, &c. See pp. 447 *et seq.* and map.

Fig. 19. Descending order of the strata exposed by the road descending from Tortworth Green to Falfield. A thin zone of Upper Silurian Rocks dips under the Old Red Sandstone, and small arches of Lower Silurian Rocks, rising in the vale, are flanked on the west by Old Red Sandstone. See pp. 447, 455.

Fig. 20. Traverse from Thornbury to Wickwar across the two axes exhibited in f. 18., but in a more southern parallel. The eastern line of elevation is marked by the highly inclined position of the Old Red Sandstone, flanked on the east by unconformable strata of New Red Sandstone, which are surmounted by lias and inferior oolite. The western elevation is seen in Milbury Heath, where the Old Red Sandstone is thrown up "en dôme." The Carboniferous Limestone and coal of Cromhall occupy a trough between these ridges of Old Red Sandstone. The Dolomitic Conglomerate forms an irregular fringe, adherent to the edges of the inferior strata, though at Thornbury it is very slightly unconformable to the underlying Old Red Sandstone, the conglomerate of the one appearing almost to graduate into that of the other. See pp. 447 *et seq.*

Fig. 21. Section of certain alternations of grit and impure limestone, which occupy the intermediate space between the chief mass of Carboniferous Limestone and the productive coal-field of Cromhall (Lower Limestone Shale). See p. 452.

Fig. 22. From Oldbury and Kington on the North to Old Down on the South, showing the fault on the south-eastern face of the western branch of the Tortworth anticlinal, near its termination. The Old Red Sandstone is thrown up on one side against the Carboniferous Limestone, and dips under it on the other. See p. 461.

Fig. 23. Silurian Group of Usk. The transverse section across this tract exhibits Silurian Rocks on both banks of the river Usk. In the centre is a dome of Caradoc Sandstone overlaid by Wenlock Limestone. The Ludlow formation is pretty fully developed, and the whole is surrounded by Old Red Sandstone, which in this figure is represented as dipping under the Carboniferous Limestone and Millstone Grit of the South Welsh coal basin, near Pontypool, &c. Numerous large boulders encumber the surface on the *exterior* of this Silurian elevation, but none are found within its inner area.

The Castle of Usk stands on a point of Upper Ludlow Rock, at its junction with the Old Red Sandstone. See pp. 438 to 441.

Fig. 24. Section in descending order from Chepstow to Usk, exposing in succession the Carboniferous Limestone more fully expanded than in any other part of this region, with its subordinate divisions of Upper and Lower Limestone Shale. The latter is seen to graduate into the Old Red Sandstone, which is also fully developed; the Upper Sandstone and Conglomerate being underlaid by cornstones, and the latter by marls, flagstones, and tiles, which graduate, in descending order, into the Ludlow Rock. A small patch of Dolomitic Conglomerate overlies the Carboniferous Limestone. See pp. 159, 438 to 441, and 453.

## PLATE 37.

(Dudley, Wolverhampton, Wallsall and Lickey.) See pp. 463 to 508.

Fig. 1. Great transverse section across the coal-field of Dudley, from the Lower New Red Sandstone of Sandwell Park on the east, to rocks of the same age near Kings' Swinford on the west; showing an upcast of the coal at each flank of the field, by which the intermediate tract of carboniferous strata is exposed. Domes of Wenlock Limestone, near Dudley, rise through the coal measures, thus separating one portion of the field from the other; and the same rock, when not upraised, is found beneath the coal at Dudley Port. See Map and woodcuts, p. 464.

The Lower New Red Sandstone of West Bromwich has been penetrated by the Earl of Dartmouth, and at a depth of more than 300 yards, coal 10 to 12 feet thick was found beneath it, though in a troubled condition, and with some protrusions of trap. This spot is three-quarters of a mile distant from what was in ancient times considered the limit of the coal-field. Since the plate was engraved Lord Dartmouth has met with the 10-*yard coal* under the red sandstone, by driving works westwards or towards the coal-field. See Appendix, p. 728.

The precise character of the eastern boundary fault of the old coal-field is taken from a shaft section of Mr. G. Bennett. The faults forming the Dudley trough are traversed obliquely. Towards the western edge of the field the trap of Barrow Hill rises in a conical form, with radiating dykes, the coal strata on its flanks being dismembered and altered, and the tract between it and Kings' Swinford powerfully affected by faults. See woodcut, p. 500.

Coal has not yet been worked beneath the Lower New Red Sandstone of Himley and Kings' Swinford, on the western side of the field, but trials to reach it are now in progress. In this section, the 10-yard and lower coal, as well as the underlying Silurian Rocks, are exhibited. See pp. 464, 487, 480 *et seq.*

Fig. 2. From the coal-field near Tipton, across Kettle Hill and the Wren's Nest, showing a dome-like elevation of the Wenlock Limestone, and the lower carbonaceous sandstone and grit of Gornals resting on Silurian shale.

To the west, the Ludlow Rocks rise at Turner's Hill, flanked by a thin band of poor coal measures, which is overlaid by the Lower New Red Sandstone of Himley. See pp. 464 *et seq.*, 482.

Fig. 3. From the New Red Sandstone of the Barr Beacon on the east, to the Lower New Red near Wolverhampton on the west; exhibiting Wenlock Limestone and shale near Wallsall, which plunging rapidly beneath the coal measures, constitute the "limestone" or boundary "fault." The trap of Pouk Hill appears in the centre, with highly dislocated strata on its flanks. The western edge of the coal-field is marked by a peculiarly oblique fault, as proved near Wolverhampton.

The iron-stone and lower coals are alone displayed in this portion of the coal-field. See pp. 464 *et seq.*, 480, 489, 503.

Fig. 4. From the edge of the 10-yard coal-field near Ettingshall on the east to the New Red Sandstone west of Sedgeley, exposing the gradual outcrop of upper and lower coal measures on slopes of Upper Silurian Rocks. The latter rising into undulating and broken domes, throw off to the west a thin band of coal measures, which is surmounted by conformable Lower New Red Sandstone. The Ludlow Rocks are well exposed in Sedgeley Beacon and Turl's Hill, including a course of Aymestry limestone. The Wenlock Limestone is fully developed in the southern end of Hurst Hill, and in a highly dislocated condition. See pp. 481, 487.

Fig. 5. Section across the Hayes near the south-western end of the Dudley coal-field, exposing a narrow ridge of Ludlow Rocks, including beds of limestone, flanked by highly inclined coal measures. See p. 483.

Fig. 6. Section to prove, that as the 10-yard coal ranges up to the southern limit of the coal-field and is lost by a fault only, there is every reason to conclude, that the same thick coal will be found at a lower level beneath the Lower New Red Sandstone and beyond the fault. The extent of the fault is of course hypothetical. See p. 506.

Fig. 7. From the trap of Lickey Beacon on the west and by north, across the Lower Lickey quartz ridge on the east and by south; showing how the altered Caradoc Sandstone, and an overlying band of impure limestone, pass beneath a thin course of coal, and the latter under the Lower New Red Sandstone. See pp. 57, 492 *et seq.*

Fig. 8. From the hill south of Lickey Beacon, on which Lord Plymouth's monument is placed, to the Lower Lickey quartz ridge, to show a dip of the quartz rock directly the reverse of that in fig. 7. (a parallel distant half a mile only). The Lower New Red Sandstone at its junction with the quartz rock shows symptoms of having been partially disturbed, as in Pl. 36. figs. 5 and 7.

(In figs. 7 and 8, the numerous joints transverse to the laminæ of deposit which characterize the quartz rock are indicated by dotted lines.) See pp. 57, 492 *et seq.*

Fig. 9. Nucleus of trap (compact felspar rock) between Kendal End and Barnt Green, marking the termination of the Lower Lickey Ridge, and explaining that the quartz rock here, as at the Caradoc and Wrekin, (Pl. 29. f. 11. and Pl. 31. f. 4.) is a Lower Silurian Sandstone altered by volcanic action. See p. 495.

# APPENDIX.

## A.

*Keuper Marl and Sandstone and Bunter Sandstone.*

ALTHOUGH the subdivision of the Keuper or Upper Formation of the New Red System into overlying and underlying marl, with a subordinate bed of sandstone, is accurately given in the section attached to the Map and in Pl. 29. f. 1., and is also laid down upon the Map, the details were not completely worked out when the chapters on it were printed. The range and fossil contents of this thin-bedded sandstone (surmounted by red and green marls and underlaid by saliferous and gypseous marls) have since been pointed out by Mr. H. E. Strickland and myself, and our memoir thereon is now printing in the Transactions of the Geological Society. (See also Proceedings of the Geological Society, vol. ii. p. 563.) In that memoir we offer a number of transverse sections in Worcestershire and Warwickshire, which not only explain the position and contents of the Keuper Sandstone as subordinate to the *Red Marl,* but show that the whole formation is immediately underlaid by light coloured and red sandstone (that of Ombersley, Bromsgrove and Warwick), which is charged with peculiar plants (*Echinostachys oblongus,* Brongn. and others), and with fishes' teeth, remains of Saurians, &c., discovered by Dr. Lloyd of Leamington. This sandstone of Bromsgrove and Warwick is the New Red Sandstone (*Bunter Sandstein*) and is represented in this work by the rocks of Grinshill and Hawkstone in Shropshire. The Red Sandstone and conglomerate of Coventry and Allesley with silicified coniferous wood, described by Dr. Buckland, Geol. Proc., vol. ii. p. 439, and which I have recently examined, is of the same age.

The Keuper Sandstone is not only distinguished from the subjacent red sandstones by its position *in the overlying* marls and by its thin beds, but also by its peculiar fossils, among which are *Posidonomya minuta, Hybodus Keuperi,* and an undescribed species of Saurian, and by not containing the plants of the *Bunter Sandstone.* I have to correct an expression made use of at page 30, where I say that the Red Marl is never inclined at a greater angle than 15° in Gloucestershire or Worcestershire; since the early chapters were printed I found, on examining the country with Mr. Strickland, that, upon the line of elevation of Inkberrow, the Keuper at Walls' Farm dips 25°. (See our joint Memoir.)

## B.

*Pitchford (Bitumen, &c.).*

The bituminous exudations at this place have been briefly alluded to, p. 94, in describing the Shrewsbury coal-field. I am informed by the Earl of Liverpool, to whom the property belongs, that the bitumen is no longer collected for medicinal or other purposes. I perceive by reference to Gough's edition of Camden's Britannia, that *salt* as well as coal works formerly existed at Pitchford, and, it is added, that they were destroyed by water. (see Phil. Trans. No. 228.) I have, I trust, clearly shown that the coal measures of this

tract are of extreme tenuity, because fundamental rocks of high antiquity rise near to the surface. Though probably worthy of notice in early days, when carbonaceous deposits, however poor, were worked, if only of easy access, it is manifest that in the present times, when so many valuable coal seams are wrought in the neighbourhood, the attempt to open coal-pits near Pitchford would be ruinous. The salt alluded to was probably made from a salt well issuing from the carbonaceous rocks?.

In readverting to the origin of the bitumen which abounds in this part of the region, both in coal strata, as at Pitchford, and at Coal Brook Dale (see p. 204), and also in the ancient Cambrian Rocks of the Longmynd, Lyth and Haughmond Hills, where it issues from cracks, and often near points of intrusive trap; I may add, that the view which I took (see pp. 265 and 266) is completely confirmed by subsequent observation at the Shelve Mines. (See F., p. 732.)

## C.

### *Newent Coal-field.*

In the diagram, p. 155., which represents a fault near the mineral spring of Newent, the subjacent strata on the east are supposed to be thrown up, and thus the coal beds are hypothetically exhibited as lying nearer to the surface than on the western side of the fault. I beg my readers to place no reliance on this merely *possible* case, and to bear in mind, that if beds of coal should ever be detected beneath the New Red Sandstone to the east of Newent, they are just as likely to occur in *depressed* as in upheaved positions. This point can be determined alone by trials. I have adduced abundant reasons to dissuade any one from embarking in coal works to the *north* or *south* of Newent, it being demonstrated that the coal-field *thins out entirely* in those directions between the New and Old Red Sandstone. (See p. 154.)

## D. (1.)

### *Coal-fields under the New Red Sandstone of the Central Counties.*

In corroboration of my belief that productive coal measures would be found beneath the New Red Sandstone of the central counties, I have to announce that the enterprise of the Earl of Dartmouth, so much alluded to in the previous pages, (pp. 58, 466, 476, 507,) has been completely successful, and that 10 yard coal of the best quality has been won beneath the Red Sandstone of West Bromwich. The shafts first sunk proved to be upon a line of dislocation which, as I have previously explained, is the prolongation of the upcast of the Silurian Rocks of Walsall and Tame Bridge, viz. from N.N.E. to S.S.W.; whence I always supposed that the trial drifts made to the East and N.E. were not likely to prove advantageous. These workings confirmed, indeed, the speculations of the geologist, in bringing to light the existence of some points of trap-rock, accompanying broken unproductive coal measures and Silurian Rocks. The latter, when followed to the N.E., were found to be simply covered by the Red Sandstone, to the entire exclusion of the coal strata. No sooner, however, was a drift carried to the West or towards the old coal-field, than it was successful (see p. 508); the thick coal having been already followed for about 200 yards to the West and S.W. without disturbance, dipping gently with the slope of the ground towards Oldbury, and rising slightly to the West. Having thus proved the value of the ground, Lord Dartmouth has leased it to Messrs. Eaton and Salter, to both of whom I am indebted for much obliging information, and to the latter for having preserved so accurately, under his Lordship's direction, the produce of the trial shafts, accompanied by illustrative plans and sections. New shafts (the Victoria Pits) are opening about 1000 yards to the West of the first sinkings, and, judging from the untroubled appearance of the Red Sandstone through which they are passing, I am disposed to think that this speculation will altogether

be most fortunate, and that the plateau extending westwards from Christchurch will be found to contain below it one of the least disturbed and, consequently, most valuable parts of the South Stafford Coal-field.—(Nov. 8, 1838.)

I may further add, that in making a tunnel under the Wyrley and Essington Canal, on the line of the Birmingham and Liverpool Railroad, north of Wolverhampton, after cutting away the gravel and red clay, (probably a part of the Lower New Red,) the workmen came upon coal, smut, &c., cropping out towards the Wolverhampton basin. This fact, communicated to me by Mr. John Barker of Wolverhampton, tends to confirm my belief that the Staffordshire and Shropshire coal-fields are simply upcast portions of the same carbonaceous tract, and that coal may hereafter be worked in the intervening space, though probably at a considerable depth beneath the Red Sandstone.

I have previously explained to my readers, that to attempt such trials with any reasonable prospect of success, they should feel certain that the Red Sandstone which they may endeavour to penetrate, is really the *Lower New Red*; and further, that their first operations are not commenced at too great a distance from the boundary fault of a good coal-field. To search for coal far to the east, for example, of the Staffordshire coal-field, particularly in those parts where older rocks are thrown up through the cover of New Red Sandstone without the trace of coal, would be very absurd: similar endeavours, on the contrary, to penetrate the Lower New Red Sandstone in the vicinity of tracts, such as the Bredon and adjoining hills of Leicestershire, where the old slaty rocks (Cambrian) are flanked by zones of Carboniferous Limestone and coal, is clearly an operation to be encouraged. On this point, indeed, I may now speak confidently, from the result of a highly successful trial made (unknown to me) since the pages relating to this subject were written; for Mr. George Stevenson, the celebrated mining-engineer, has actually penetrated the New Red Sandstone adjacent to the Bredon Hills, and is now working a coal-field of much greater value than any which has been naturally thrown up to the surface in that neighbourhood. In this case Mr. Stevenson applied, with his well-known energy, the same means by which he had been accustomed to sink through the Magnesian Limestone and Lower Red Sandstone of the northern counties.

The tract alluded to in Leicestershire, and which is thus proved to be one of great importance in supplying the inland districts with coal, was last year re-examined by Professor Sedgwick, who had previously explained the prominent relations of its older rocks, and he informs me that he found the Red Sandstone which there overlies the coal-measures to be in every respect analogous to the formation I have described in Shropshire, Staffordshire, and Worcestershire, i. e. containing much calcareous sandstone and grit, with traces of plants and coal in its lower members; while the upper coal-measures present a thin band of apparently "freshwater limestone," similar to that which I have pointed out in the same position in the Shrewsbury, Coal Brook Dale, and other coal-fields. (See pp. 83. *et seq.*)

## D. (2.)

### *Outcrops of the Dudley Coal.*

The lowering of the roads during the last summer near Dudley has exposed the outcrop of the bottom beds of the coal measures. About half a mile from the town, on the road to Birmingham, such an outcrop had been long visible, and is indeed noticed by Mr. Kier in his account of this tract; but by cutting through the rising ground in question, the coal-beds have been completely exposed, and are seen to rest at their western extremity upon the shale of the Wenlock (Dudley) Limestone, the beds of which, rising gently from beneath the town and the Castle Hill, are suddenly arched, and plunge to the E.N.E. at an angle of 30°, surmounted conformably by coal measures. So conformable, indeed, are these Silurian and carboniferous rocks, and so much do they appear to graduate into each other, that it is obvious the one must have been deposited upon the other in the

manner expressed in the upper woodcut, p. 465., the curvature and inclination of both having been caused by upheaval from beneath (lower woodcut, p. 465.). The carboniferous beds in question consist, in ascending order, of shale, grit, and sandstone, with ironstone concretions, overlaid by a seam of coal and shale; then follow alternations of shale, ironstone, sandstone, and grit, including the *Espley Rock* of the miners (p. 476.), the whole covered by coal, which dips under thin bedded, yellowish grit and sandstone, and passes under the productive coal-field.

Again, at Shaver's End, above Dudley, the new cuttings beyond the turnpike-gate have laid bare two coal seams, which are thrown off sharply to the N.E., and with great undulations to the S.E., the light-coloured carboniferous sandstone appearing in a broken, uneven-edged mass between them. These highly-disrupted relations of the lowest beds of the coal-field are just what we should expect to find in this part of the district, where volcanic action has been so rife, and has repeatedly forced up the inferior strata to the surface, the points of the volcanic rock often piercing them.

Having revisited the Devil's Elbow, near Netherton, alluded to p. 499, I conceive that the hard rock cut through by Brewin's tunnel is one of these points of eruptive trap: it throws off the coal measures to the S.E. in the manner described by Mr. W. Mathews, while the sandstones and grits which lie towards Netherton Church are arched over the trap in separate hillocks.

## D. (3.)

*No Coal in the Old Red Sandstone.*

It was stated in a note, p. 189 *ante*, that although unknown in the region described in this work, certain coal-seams do occur in the Old Red Sandstone of the South of Scotland. Although this was the opinion of some modern observers, it would now appear that a certain Red Sandstone of Berwickshire which was supposed to be Old Red, is the Lower New Red, and hence the carboniferous strata associated therewith do not offer any exception to the general distribution of coal in the series of British deposits. As yet, therefore, we have no example of a coal-bearing stratum in the Old Red Sandstone.—(See Geology of Berwickshire, by Mr. D. Milne; a memoir read before the British Association for the Advancement of Science, 1838.)

## E.

*Joints.*

It was my intention to have followed out a plan, first suggested to me by Professor Phillips, of registering in a table the differences in the direction and inclination of all the faces of joints in rocks of different composition and age; but though my field-books are full of data, I am not prepared to offer them to the public.—(See Phillips's Guide, p. 173.)

## F. (1.)

*Shelve and Corndon Hills, &c.;—Lead Mines, Bitumen, &c., in the Silurian Rocks of—Antiquities of.*

The mines of these hills have been treated of at some length in reference to their geological relations pp. 227 *et seq.* They are, however, of too great importance not to be also noticed in an economical point of view, as will appear from the following table of their produce in 1835.

| | Tons of Lead. |
|---|---|
| Bog Mine ................ | 1554 |
| Snailbatch ................ | 1300 |
| Grit and Gravel............ | 685 |
| Total of Shelve Mines.. | 3,539 |

Mr. John Taylor informs me that the present produce of lead in the United Kingdom may amount to from 47,000 to 50,000 tons.

We thus see that the little Shropshire tract on which I have previously dwelt with so much *geological* interest, has hitherto produced a thirteenth or fourteenth part of the total produce of the British Lead Mines. The ore is of very superior quality, for at the Bog Mine each ton produces fifteen hundred weight of lead, and at the Snailbatch, Grit, &c., about fourteen hundred weight; while the average of the kingdom may perhaps be estimated at not more than thirteen hundred weight.

The reader who seeks for more information concerning the former condition of the Snailbatch Mine, will find an instructive short sketch of it in the memoir of Mr. A. Aikin, "On the Occurrence of *Witherite* or *Carbonate of Barytes*" in the vein-stones of that mine. (Geol. Trans., Old Series, vol. iv. First Series, p. 438.) The vein of lead ore at that period (1811) varied from twelve to thirty feet in dimensions, and the greatest depth of the works was one hundred and eighty yards.

I possess little information concerning that mine, although I have often examined the features of the surface around it.

Of the Bog and Grit Mines I met, I have already spoken (as much as seemed needful for geological purposes); but as my friend Mr. Joseph Walker, one of the proprietors of the Bog Mine, has offered me information which I did not possess when the chapter on that tract was printed, I willingly add the following extract of a letter to him from Mr. W. Jones of Chester.

"The present depth of the Bog engine-shaft is 293 yards, and the lowest level 265 yards. In the upper workings, above the adit or boat-level, which is 105 yards deep, there are three distinct veins to the eastward, but two of these unite at about ten fathoms under the adit level. Thus united, they are crossed about the middle of the mine by the other vein, which in the upper part of the mine, or towards the Stiperstones, is called the 'South Vein,' and to the west, after it has crossed the other vein, will consequently be on the north side. The main vein is from 2 to 3 feet wide, and the other, which crosses it, from 6 inches to 1 foot. The two branches of the main vein not only join each other on the line of bearing, but hade towards each other and unite downwards, so that at the 20-fathom level and below we have only two veins. We have pursued this level within about 250 yards of the Stiperstones, but the work has been suspended for some time in consequence of the vein being very small and poor. I know of none of the veins in this country that have been worked up to the Stiperstones, but I have little or no doubt that they do not break through them, though undoubtedly the Snailbatch vein has been found on the other side of the Stiperstones, but whether in a continuous line, or thrown on one side, I am not prepared to say."

Those who have perused my chapter on this tract will have perceived, that I spoke of some of the lead veins having been worked up to the flank of the Stiperstones, where they were found to be deflected and cut off. I had this information from an old miner, and I have no doubt that my general view in supposing the Stiperstones to be a great wall or rider bounding this mining tract on the east-south-east is substantially correct. That a small branch or poor vein of lead should have been found (in a shifted position) on the eastern side of the Stiperstones near Snailbatch, is by no means remarkable, but rather in analogy with many examples in other tracts. See account of the Cerrig-mwyn mines, p. 366. As a matter of fact, it is, however, well known that there is no other trace of a lead vein (however small) in the Linley, Pulverbatch, and Longmynd Hills to the east and south-east of the Stiperstones, while copper veins are there in abundance. I therefore adhere to my original position, leaving chemists to speculate on it,—namely, that in a tract highly convulsed by volcanic action there are two distinct metalliferous tracts, neatly separated from each other by a wall of quartz rock,

which I have shown to be sandstone fused and altered by heat.—(See Note, p. 8, on the origin of the word Stiperstones.)

In relation to the "warm water vein" of lead ore in the Shelve district, (see p. 280), I am informed by Mr. Joseph Walker, that, upon re-opening the works to follow that vein, he convinced himself from actual examination that the water was there much hotter than in any other part of the mining ground. He also observed much mineral pitch or bitumen in the vein stuff and on the sides of the vein. Any doubts, therefore, which might have existed as to the presence of bitumen in these old rocks is entirely dispelled. There is much trap and altered rock around this spot, and the phenomenon is therefore confirmatory of my views, p. 276.

The rugged tract of the Corndon and Shelve Hills will be rendered doubly attractive by the forthcoming work of the Rev. C. H. Hartshorne, alluded to p. xxxii, in which the reader will find an account of *Druidical circles, Stones of worship*, &c., on Stapeley Hill and at the foot of Corndon.

## F. (2.)

*Heblands, near Bishop's Castle.*

Through inadvertence a point of trap rock which bursts through the Silurian strata at about one mile N. of Bishop's Castle has not been mentioned in the text, though I have twice examined it in former years. It is a hard, whitish, compact felspar rock, the eruption of which has altered the contiguous strata to some extent, giving rise to coats of impure serpentine, veins of calcareous spar, crystals of iron pyrites, breccia, and indurated schist. It is marked upon the map, and may be considered as the extreme southern point of the volcanic tract of Shelve or Corndon.

## F. (3.)

*Mines of Gogo-fau, Caermarthenshire, and Gogo, Salop.*

I have to thank the Rev. H. C. Hartshorne for having directed my attention to a letter in the Cambrian and Caledonian Quarterly Magazine, vol. v. p. 321, in which the late Mr. T. Parker describes the Roman Mines of Gogo-fau (see p. 367). It appears that this author detected a few traces of galena, and therefore he concluded that "lead was the substance sought after; but from the unconnected irregularity of the works, one part having scarce any reference to another, it must," he says, "be considered as a *bunching mine*, which in some degree accounts for the wideness of the excavations, and that so soon as one bunch or mass of ore was cleared away they broke the ground in all directions in search of another, finding no string or metallic leader, as in more regular mines, to guide their course."

Again, in a learned historical inquiry into the situation of the gold mines of the ancient Britons, the mines of Gogo-fau are also described (Cambrian Register, vol. iii. p. 41), and the author states, that Sir Joseph Banks and several other persons who visited these caves or galleries were of opinion that they had been worked for gold. The reader will there find a good explanation of the manner in which the water was conducted to stream the works in question, and some ingenious speculation on the antiquities, both British and Roman, around Cynfil-Caio, with a version of the legend of the Five Saints (Llan-pump-Saint) differing from that which I have given.

In his excellent statistical account of the parish of Llanymynych, (Cambrian Register, vol. i. p. 265,) the Rev. Walter Davies gives some curious information respecting the great mine of the *Ogo*, which runs from West to East, in the promontory of Carboniferous limestone before described (see p. 145), and which is clearly proved to have been a Roman work from the remains found within it. Besides various ores of copper and lead, Mr. Davies alludes to calamine and blende as of occasional occurrence, but states that the mines are now exhausted of their wealth.

## G.

*Bowlders transported by Ice.*

The chapters on superficial detritus were in the press when Mr. Lyell favoured me with the perusal of a most instructive letter from Captain Bayfield, R.N., now employed in surveying the coasts and rivers of our North American colonies, which so strikingly corroborates the views I have attempted to establish concerning the method by which our English bowlders and the associated shells have been deposited, that, with Mr. Lyell's permission, I annex an extract. After a graphic sketch of the geological features of the region, Captain Bayfield thus alludes to the case in question.

"The bed of the St. Lawrence below Lake St. Peters is full of immense bowlders of primary rocks, most of them (but not all) rolled or water-worn, or with their edges worn off by atmospheric agency, (for I do not believe that all the blocks which appear to be so, have been really water-worn). See pp. 540 *et seq.* These are principally derived from the Tertiary beds, for they abound in them, even among the shells, and at all levels; and as the terraces are worn away, the bowlders are left at the foot of the cliffs, and sticking out of sand and clay. *Torrents bring them down the steep water-courses at the melting of the snows; and when they reach the St. Lawrence, the ice moves them every spring.* I have seen a granite bowlder, 15 feet in length by 10 in width and depth, transported many yards along a meadow by this agent; and last spring I watched the lake ice (Lake St. Peter), which takes 2 or 3 days to pass Quebec every spring, and had the pleasure to observe several bowlders of considerable size, and many small stones, sand, earth, reeds and plants on their way down the river, drifting at a rate measurable by the excess of every ebb tide over the preceding flood. The latter flows $4\frac{3}{4}$ hours, at the rate of 3 knots; the former about $7\frac{1}{2}$ hours, at 4 knots. Any bowlders thus transported are liable to be dropped at various points along *the bed of the river*, as the ice gives way to the increasing temperature of the air and water in the spring of the year."

After showing how freshwater shells, seeds, plants, &c. are similarly transported and tranquilly deposited along with large blocks of stone, amid marine shells, Captain Bayfield gives practical illustrations of the power of the ice of one season in removing large bowlders and deep stakes, which he had caused to be placed in certain positions. These were entirely carried away and replaced by other bowlders, while in the same season a mass of granite, containing 1500 cubic feet, and which he had particularly marked, was transported several hundred yards from its observed position. Again, in speaking of the bowlders which occur in the younger Tertiary deposits, he says, "They are found in the cliffs at different levels, not resting upon each other, but as if they had been dropped there at widely different times, during a long period, in which a quiet deposition of clay, sand and gravel had been going on, and in which the various genera of testacea had lived and died. Some of the shells are of course broken, and some of the valves are separated, as is the case in the bottom of the present seam; but many have both valves together, although they separate when taken up, because the ligament no longer exists. All idea of these shells (together with the sand, clay and bowlders) having been drifted together into their present positions must be given up at once, when I state the fact, that the *Terebratulæ psittaceæ*, which you know are so fragile that the smallest stones would be sufficient to destroy them, if carried along with a moderate degree of violence by moving water, are found with their valves together, and their long and brittle teeth entire as when they were living."

"The whole of the facts, which I have neither time nor space to dwell upon in this letter, lead me to infer that these numerous erratic blocks, from whatever source originally derived, have been dropped from time to time (from ice floes) on the bed of the Tertiary sea."—Extract of a Letter from Captain Bayfield, R.N., to Mr. Lyell, November 1837.

## H.

*Landslips.*

Besides the landslips of Ludlow and Woolhope, one has been partially adverted to, which occurred near Buildwas on the Severn, 12 miles east of Shrewsbury. The reader will find this landslip, "The Birches,"

described in Gough's edition of Camden's Britannia, vol. ii. p. 418. It took place on the 26th of May 1773. The ground was much heaved up and down, 18 acres being moved, leaving a chasm 12 to 14 yards wide. The course of the Severn was impeded by the mass which was advanced into it, and the river was flooded back. According to Dr. Gough, shocks of earthquake, and which he compared to those of Calabria, were felt during two days, throughout the adjacent country.

## I.

*Silurian Rocks of Cumberland and the adjacent tracts.*

In the course of this summer (1828) and since the greater part of this book was printed, I made a rapid survey of Cumberland and the adjacent parts of Lancashire and Yorkshire, in which Professor Sedgwick and Professor Phillips had indicated the existence of some equivalents of the Silurian Rocks. (See the small map of England engraved in the corner of the large one.)

The great mass of the slaty rocks of that region belongs unquestionably to the Cambrian system, and Professor Sedgwick is disposed to think that the fossiliferous limestone of Coniston-water-Head is of the same age as that of Bala. True Silurian Rocks, however, and of considerable dimensions, are interposed between the Cambrian Rocks and the Old Red Sandstone, particularly along the southern boundary of the former. Such are largely developed, for example, between Kendal and Kirkby Lonsdale, reposing near the former place on Cambrian Rocks, and at the latter dipping under the Old Red Sandstone of the valley of the Lune.

My attention was first called to that district by my friend the Rev. J. H. Fisher, vicar of Kirkby Lonsdale, and, on recently visiting him, I added some fossils to a collection previously sent to me by him. Other specimens are to be seen in the New Museum of Kendal, and Professor Sedgwick possesses some which I have not seen.

Orthoceratites occur, particularly *O. annulatum*, Pl. 9, f. 5, *O. gregarium*, Pl. 8, f. 16, and *O. eccentricum*, Pl. 13, f. 16. Among the shells in the uppermost beds are casts resembling *Avicula retroflexa*, Pl. 5, f. 9, and *Cypricardia amygdalina*, Pl. 5, f. 2; and in the same beds near Kendal, *Atrypa affinis*, Pl. 6, f. 5, *Leptæna sericea*, Pl. 19, f. 1, some forms of *Orthis*, &c., one nearly resembling *O. canalis*. On the whole, the shells collected near Kirkby Lonsdale seem to indicate Upper Silurian, and those of the underlying strata near Kendal (which I examined, however, in great haste) Lower Silurian. Professor Sedgwick will elucidate this subject, when all the fossils collected shall have been properly examined and compared. The transverse section from the Old Red Sandstone at Kirkby Lonsdale, through the Silurian System, to the old slaty rocks and the intrusive granite of Shap, is particularly clear and instructive.

## K.

*Fossil Footsteps in the New Red Sandstone.*

I may state, that the impressions of the feet of some unknown animal have been recently discovered by Dr. O. Ward on the surface of the New Red Sandstone at Grinshill, Salop (see p. 40), and that the specimens (which I have not yet seen,) are deposited in the public Museum at Shrewsbury. I must also add, that prints or footsteps of the *Cheirotherium* have been discovered in the red sandstone which occupies the promontory of Cheshire, between the Dee and the Mersey. The most clearly-distinguished slabs are in the museum of the Liverpool Institution: Dr. Buckland gave a notice of them at the meeting of the British Association at Newcastle, and I understand that Sir Philip Egerton is preparing a more detailed account. In the mean time, sections illustrating the strata have been communicated to the Geological Society by Mr. J. Cunningham, while these pages are going through the press.

THE END.

# INDEX.

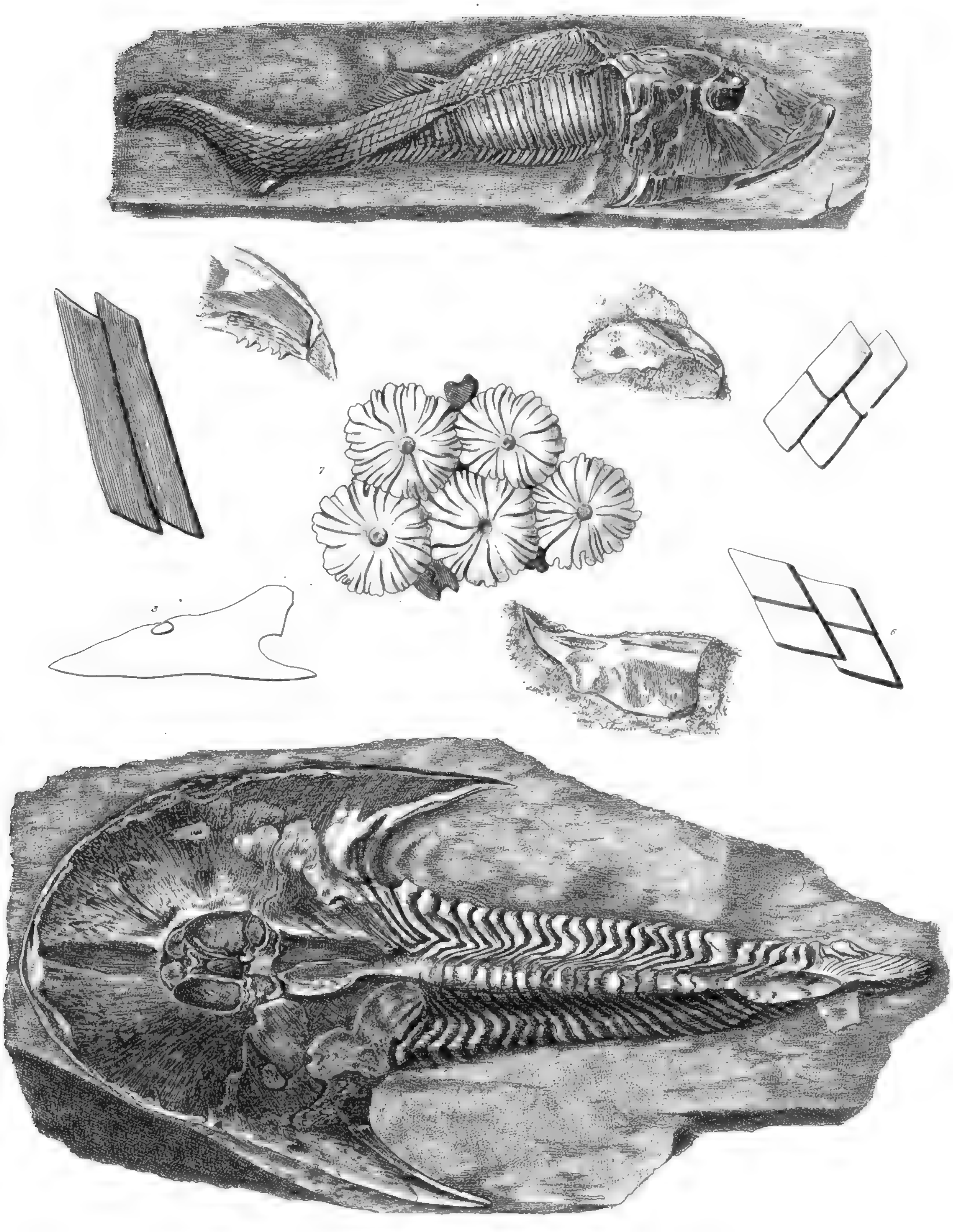
*** No organic remains are cited in the Index, except the genera of Fishes and Crustaceans, and the *new* genera of Shells and Zoophytes, a reference to every fossil species which is figured being given in the table, p. 703, *et seq.*

ERRATA (ADDITIONAL).

P. 688, l. 8, *for* Robeston Walthen *read* Robeston Wathen.
P. 697, l. 23, *for* transversely situated *read* transversely striated.

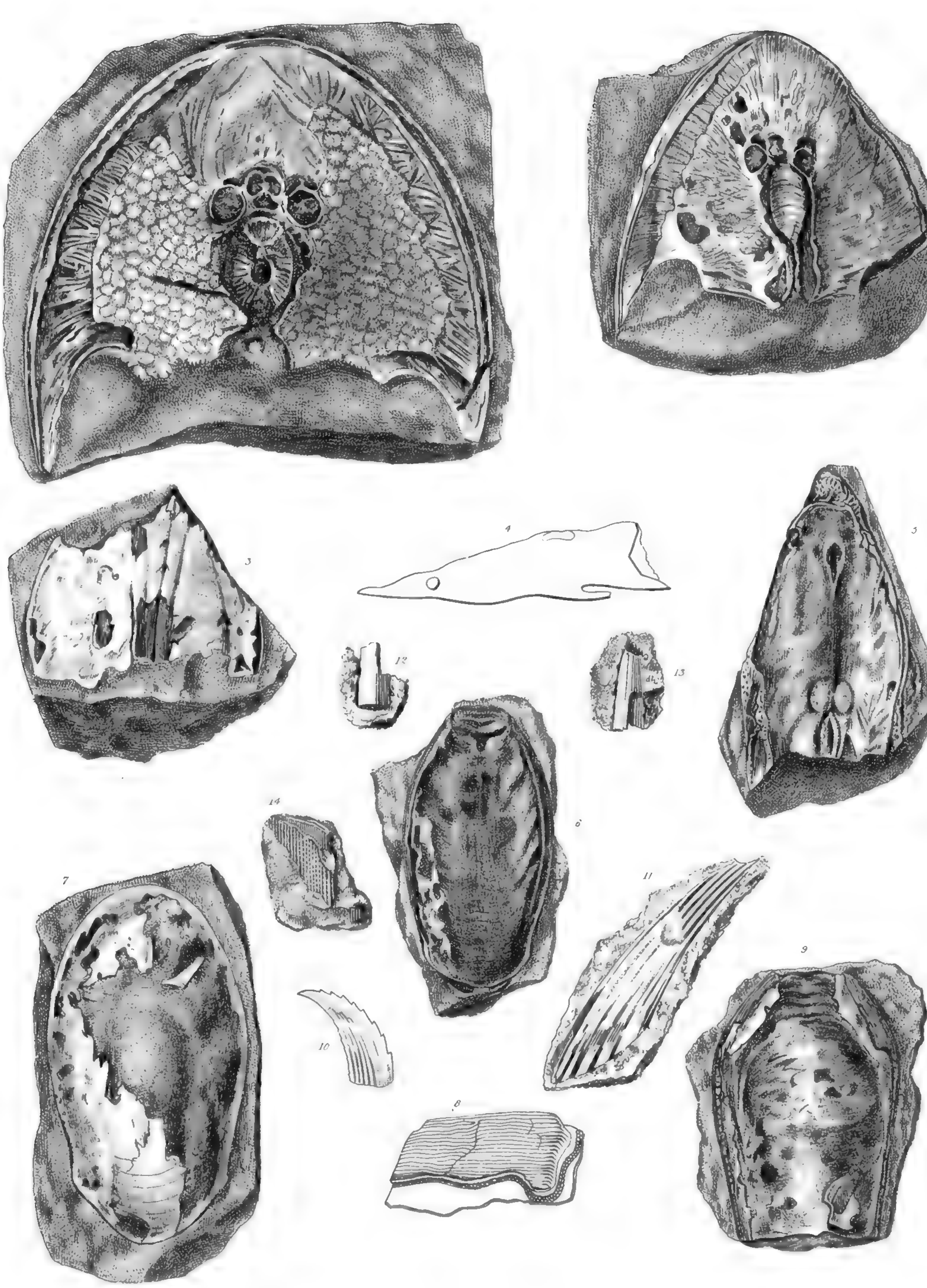
FINIS.

Printed by Richard and John E. Taylor, Red Lion Court, Fleet Street.



F. 1.2.3 Cephalaspis Lyellii (Agass)
4. Scales of the side mag^d
5. back d°
6. tail d°

F. 7 Scales of the head mag^d see Pl. 2, f. 1
8. Portion of the disc of the head ?
9. Spine of [illegible] fig 1
10. The same mag^d

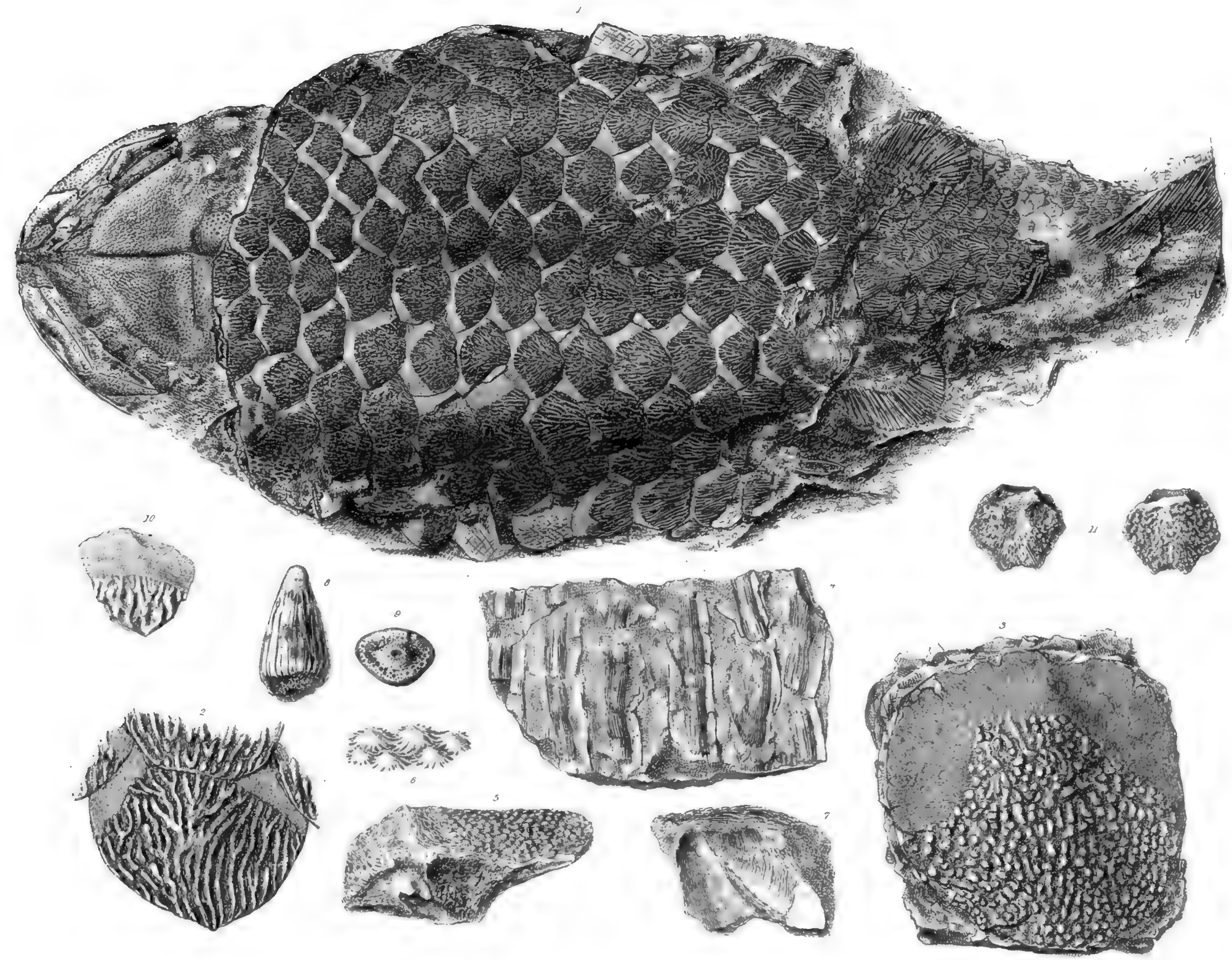



F. 1 2 3 Cephalaspis Lyellii. (Agass.,
4. 5. rostratus (Ag.
6 Lewisii (Ag.
7 9 Lloydii (Ag.
10 11 Onchus arcuatus (Ag.
12 13 semistriatus. (Ag.
14 Ctenacanthus ornatus. (Ag.

OLD RED SANDSTONE.

(FISHES.)

Pl. 2.bis



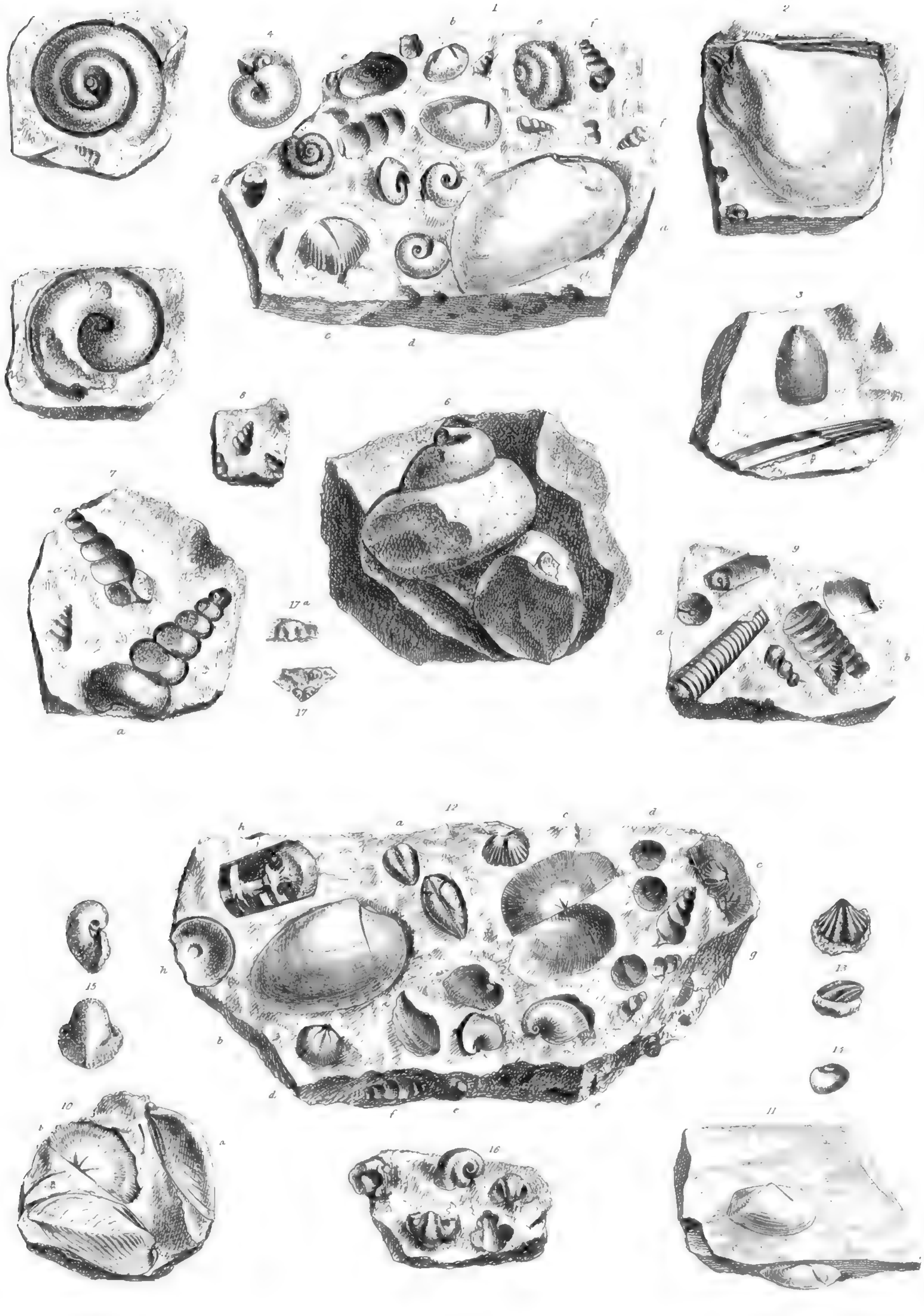
F 1 Holoptychus Nobilissimus (Agass.) ½ nat. size
2. A ventral scale of f. 1 nat. size.
3 Tuberculated scale of Holoptychus. (Ag.)

F 4. Processes beneath the scales of Holoptychus. (Ag.)
5. Part of operculum of d°
6. Surface of f. 5 mag^d

F 7 11 Fragments of Ichthyolites.
8 9 Tooth of Holoptychus or Megalicthys? (Ag.)
10. Fragment of scale of Holoptychus. (Ag.)

## OLD RED SANDSTONE.

(SHELLS.)




F. 1 a. Pullastra lævis
b. 12 a. Cucullæa antiqua
c. Terebratula Nucula
d. 4 Bellerophon carinatus
e. 5 Trochus helicites

F. 1 f. Turritella gregaria
2 Avicula rectangularis
3 Lingula cornea.
6. Turbo Williamsii
7. a. 12. f. g. Turritella obsoleta.

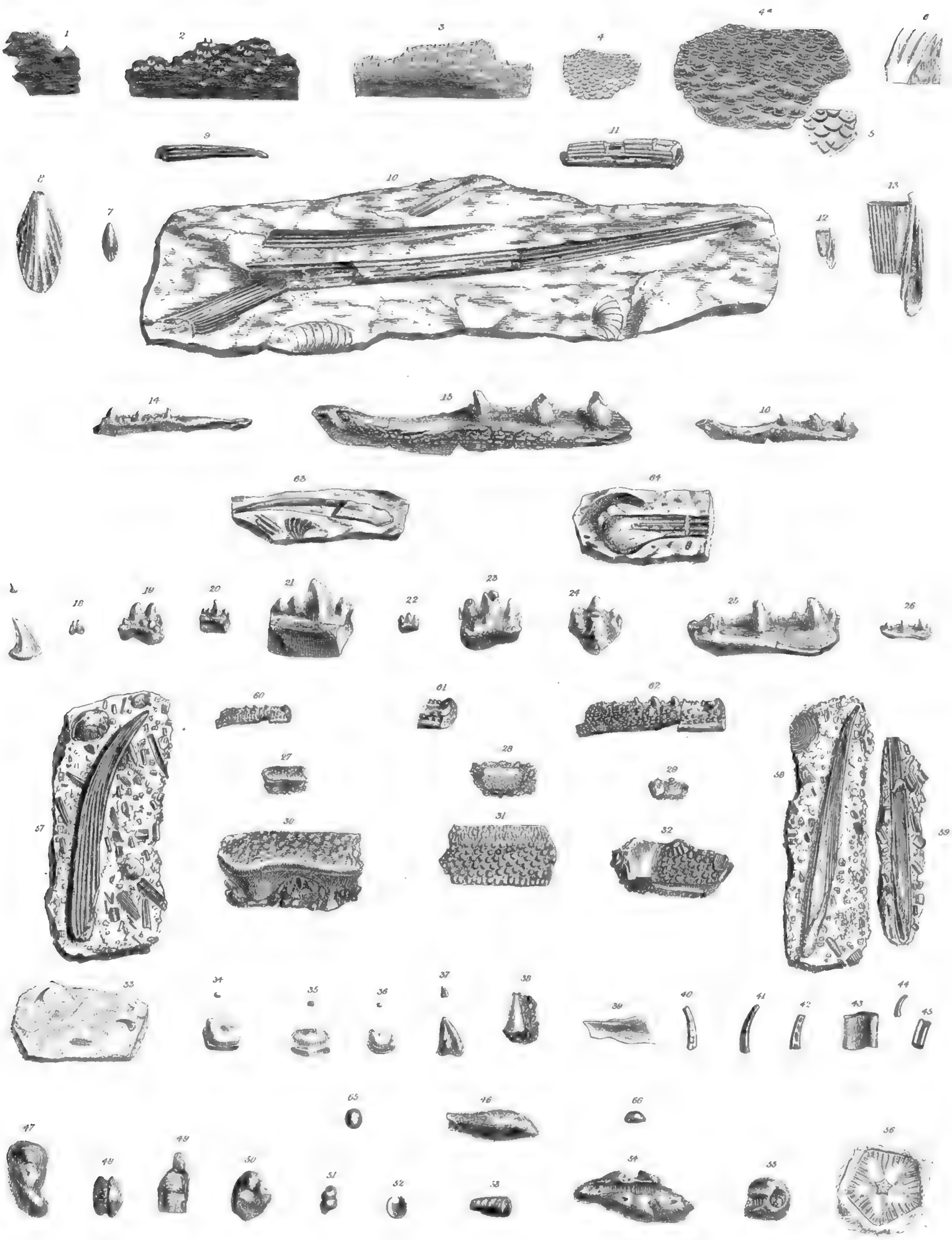
F. 7. b. 8. Turritella conica
9. a. Orthoceras semipartitum
b. tracheale
10 a. Cypricardia cymbæformis
b. 12. c Leptæna lata.

F. 11. Cucullæa Hardingi
12. b. — ovata
d. Orthis lunata
e. Bellerophon striatus
h. Orthoceras

Spirifer cuspidatus
14 Natica ...
15. Bellerophon globatus
16. — trilobatus
17 17 a mag^d Agnostus pisiformis? Koden.

UPPER LUDLOW ROCK.

(FISHES, &c.)



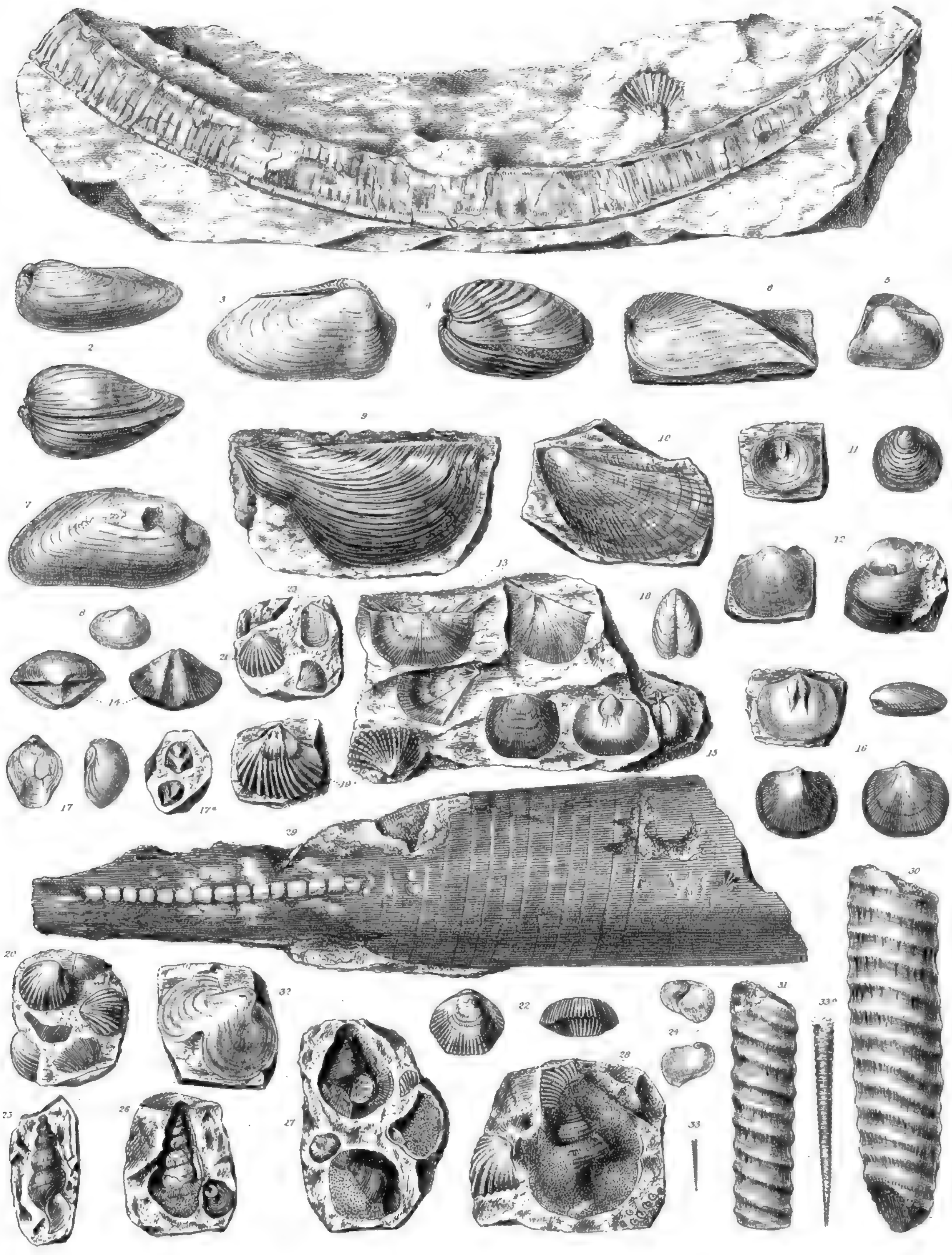
F. 1, 2, 3. Skin or Shagreen of Sphagodus (Agass.)
4. 4ª mag.ᵈ 5. Portions of Pterygotus problematicus (Ag.)
6. Teeth of Sphagodus pustulatus
7, 8. Shell?
9, 10, 11. Onchus Murchisoni (Ag.)
12, 13. Onchus

F. 14-16, 20, 21, 25, 26. Plectrodus mirabilis (Ag.)
17 & 33. Teeth
18, 19, 22-24. Plectrodus pleiopristis (Ag.)
27-32, 60, 62. Sclerodus pustuliferus (Ag.)
34-36. Thelodus parvidens (Ag.)
37-39. indeterminable.

F. 40-45. Rays of fins, probably Onchus
46-55. Coprolites and their contents
47, 48. Orbicula rugata
49. Lingula minima
50. Bellerophon globatus?
51. Turritella

F. 52, 53. Orthoceras semipartitum
56. mag.ᵈ Crinoidal cast in Coprolite, f. 55
57-59. Onchus tenuistriatus
63. Onchus
64. Ichthyodorulite
65, 66. Palatal bones of Sclerodus, f. 30

(SHELLS)



F. 1. Serpulites longissimus.
2. Cypricardia amygdalina.
3. ——— impressa.
4. ——— undata.
5. ——— retusa.
6. ——— cymbaeformis var.
7. Pullastra complanata.

F. 8. Nucula ?ovalis.
9. Avicula retroflexa.* (Hisinger)
10. ——— lineata.
11. Orbicula rugata.
12. ——— striata.
13. Leptaena lata (V. Buch)
14. Spirifer trapezoidalis (Dalm)

F. 15. Orthis lunata.
16. ——— orbicularis
17. 17.a Terebratula Navicula.
18. ——— canalis.
19. ——— lacunosa (Dalm.)
20. ——— Nucula.
21. ——— pulchra.

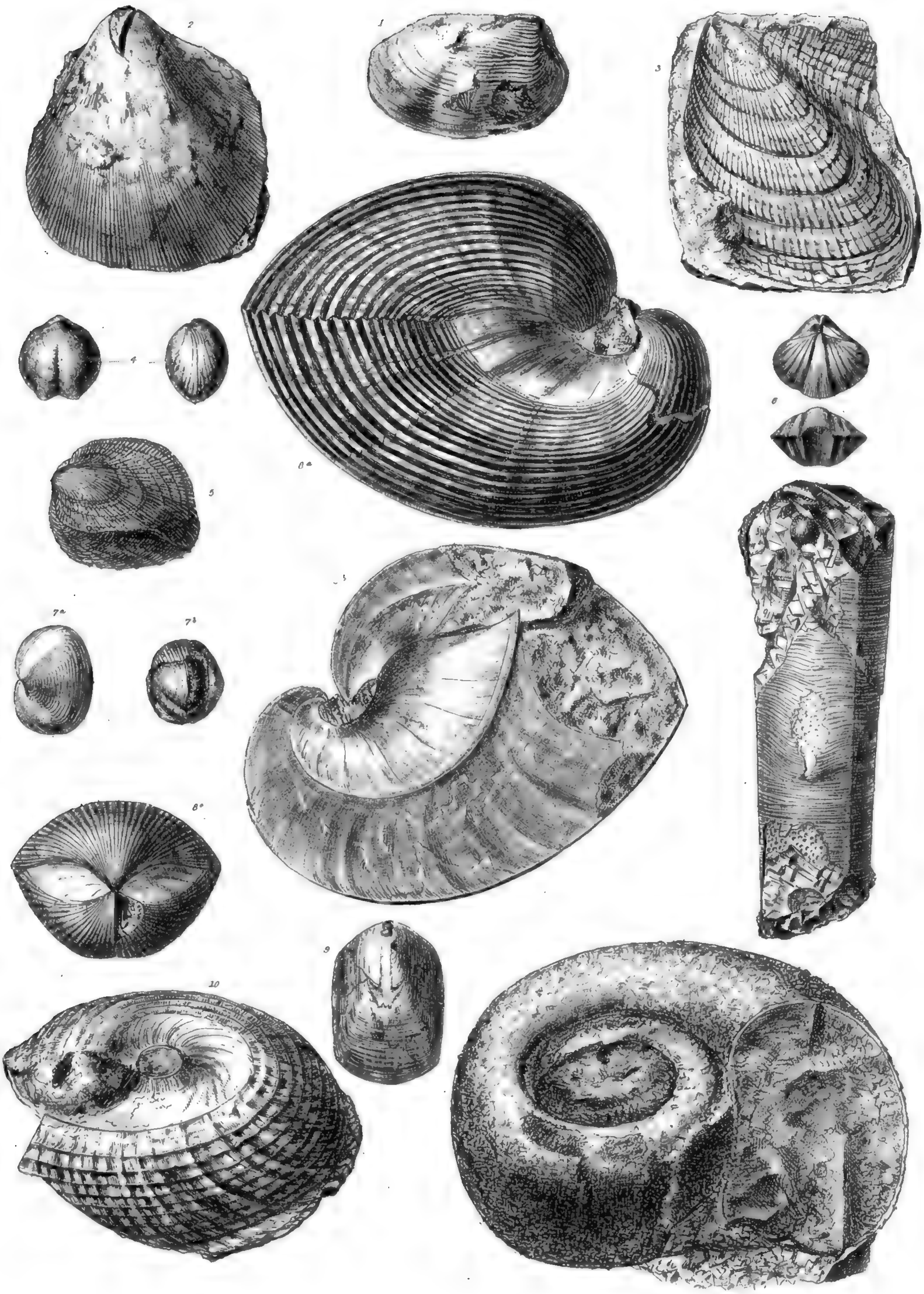
F. 22 Terebratula pentagona.
23. Lingula [illegible].
24. Natica parva.
25. Pleurotoma articulata.
26. ——— corallii.
27. Turbo corallii.
28. ——— carinatus.

F. 29. Orthoceras bullatum
30. ——— ibex.
31. ——— articulatum.
32. Bellerophon expansus.
33. Tentaculites tenuis
33.a The same magd.

# AYMESTRY LIMESTONE.

(SHELLS.)

Pl. 8.



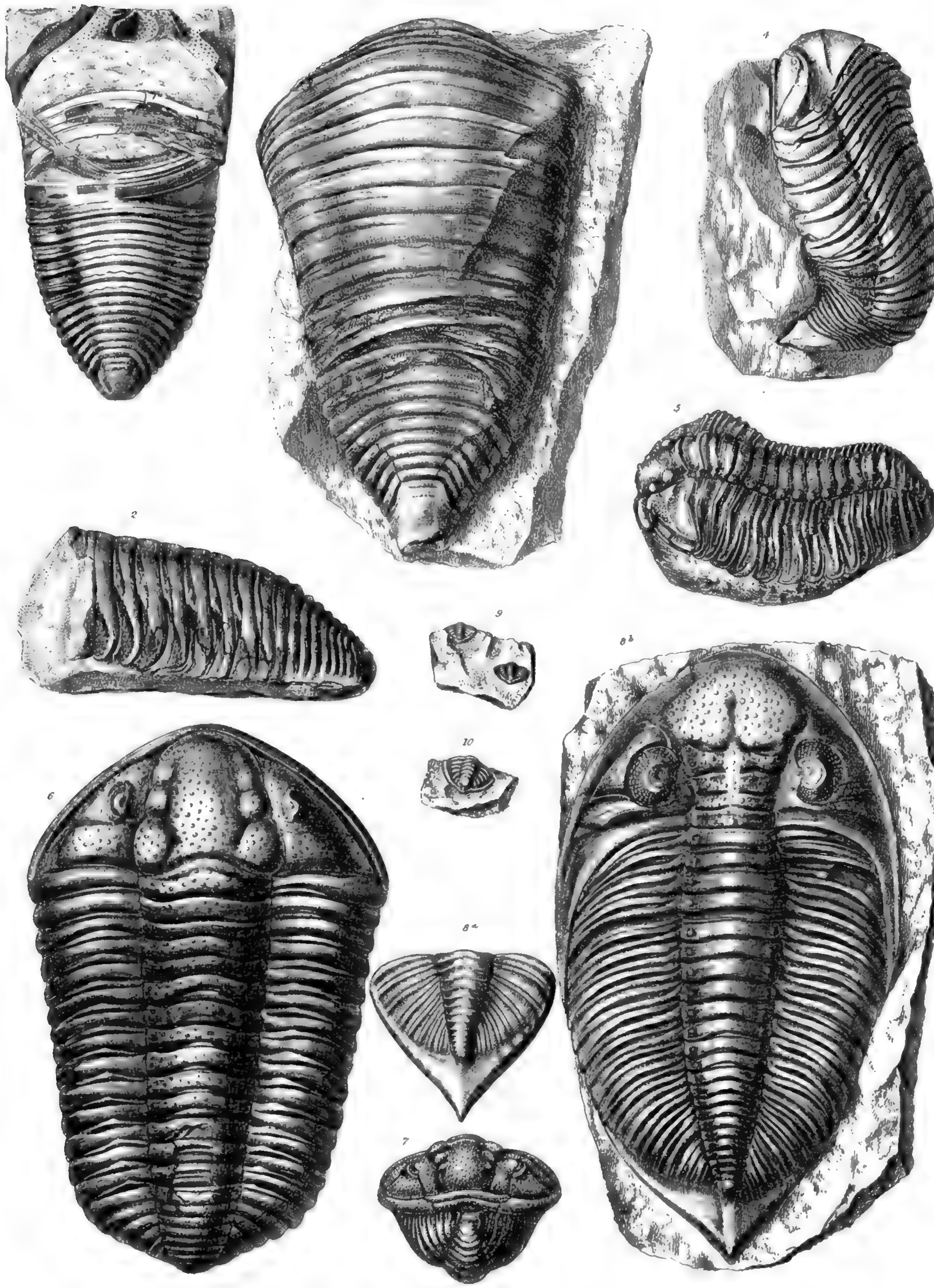
F. 1. *Mya rotundata.*
2. *Cardium striatum.*
3. *Avicula reticulata.*
4. *Atrypa didyma (Dalm.)*
5. — — *affinis (M. C.)*
6. *Spirifer interlineatus*

F. 7. *Terebratula? Wilsoni (M. C.)*
8a. *Pentamerus Knightii (M. C.) 8b. Sat. 8c. young.*
9. *Lingula Lewisii*
10. *Euomphalus carinatus*
11. *Orthoceras Mocktreensis.*
12. *Bellerophon Aymestriensis.*

# LUDLOW ROCKS.

(TRILOBITES)

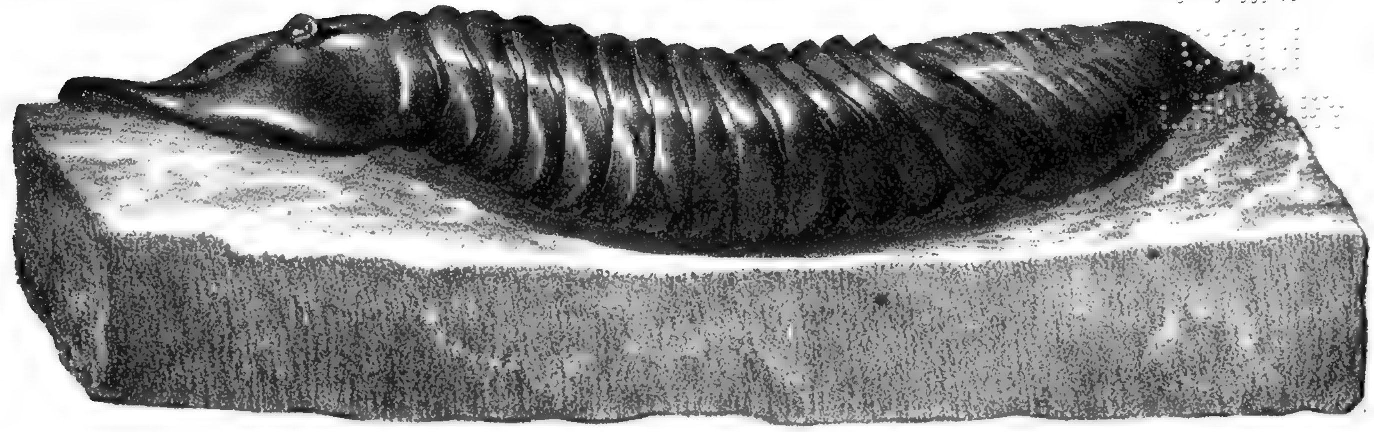
Pl. 7



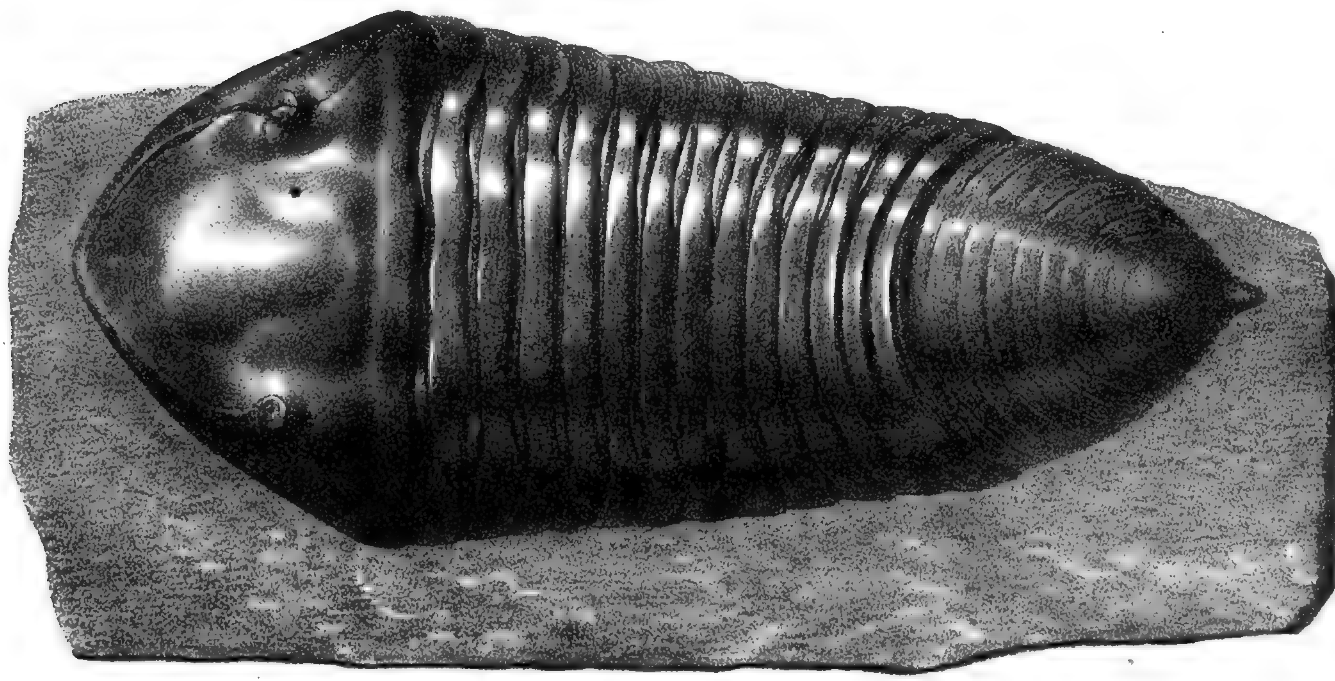
F. 1, 2. *Homalonotus Knightii.*
3, 4. ———— *Ludlensis.*
5, 7. *Calymene Blumenbachii* (Brong.)
6. ———— *major.*

F. 8^a *Asaphus caudatus* (Brong.)
8^b ———— *tuberculato-caudatus.*
9. ———— *Cawdori.*
10. ———— *sub-caudatus.*

*Fig: 1.*

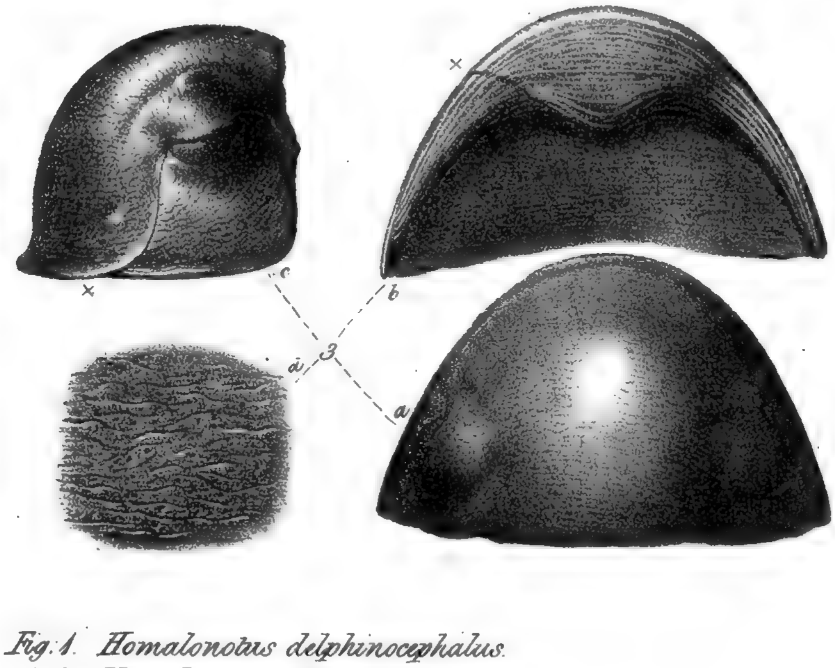


a



b

2

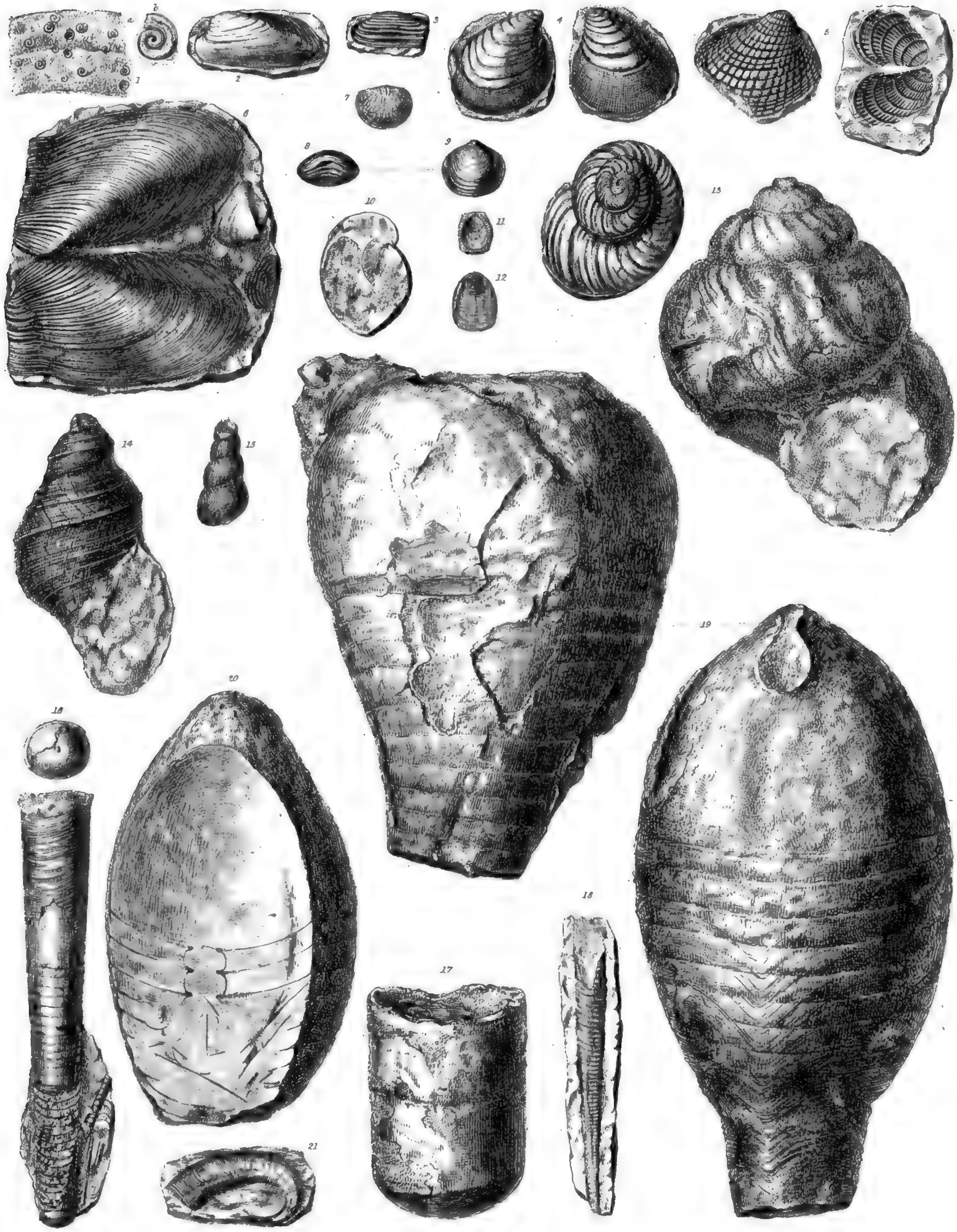



*Lithog. from Nature by G. Scharf*

*Fig: 1. Homalonotus delphinocephalus.*
*2. Homalonotus Herschelii.*
*3. a. b. c. d. Bumastus Barriensis.*

## LOWER LUDLOW ROCK.

(SHELLS.)



*F. 1. Spirorbis Lewisii. b. mag.d*
*2. Cypricardia? solenoides.*
*3. Psammobia rigida.*
*4. Cardiola fibrosa.*
*5. interrupta (Cardium? cornucopiae Goldf.)*
*6. Modiola semisulcata.*

*F. 7. Leptaena Lepisma (Dalm.)*
*8. 9. Atrypa obovata.*
*10. galeata (Dalm.)*
*11. Lingula lata.*
*12. ? striata.*
*13. Pleurotomaria undata.*
*14. Lloydii*

*F. 15. Terebra? sinuosa.*
*16. Orthoceras gregarium.*
*17. distans.*
*18. bimidiatum.*
*19. ? pyriforme.*
*20. Cyrtoceras laeve*

## LOWER LUDLOW ROCK.

(SHELLS.)

*F. 1a. Orthoceras Ludense α.*

*1b. ——— ——— β.*

*2. ——— imbricatum (His.)*

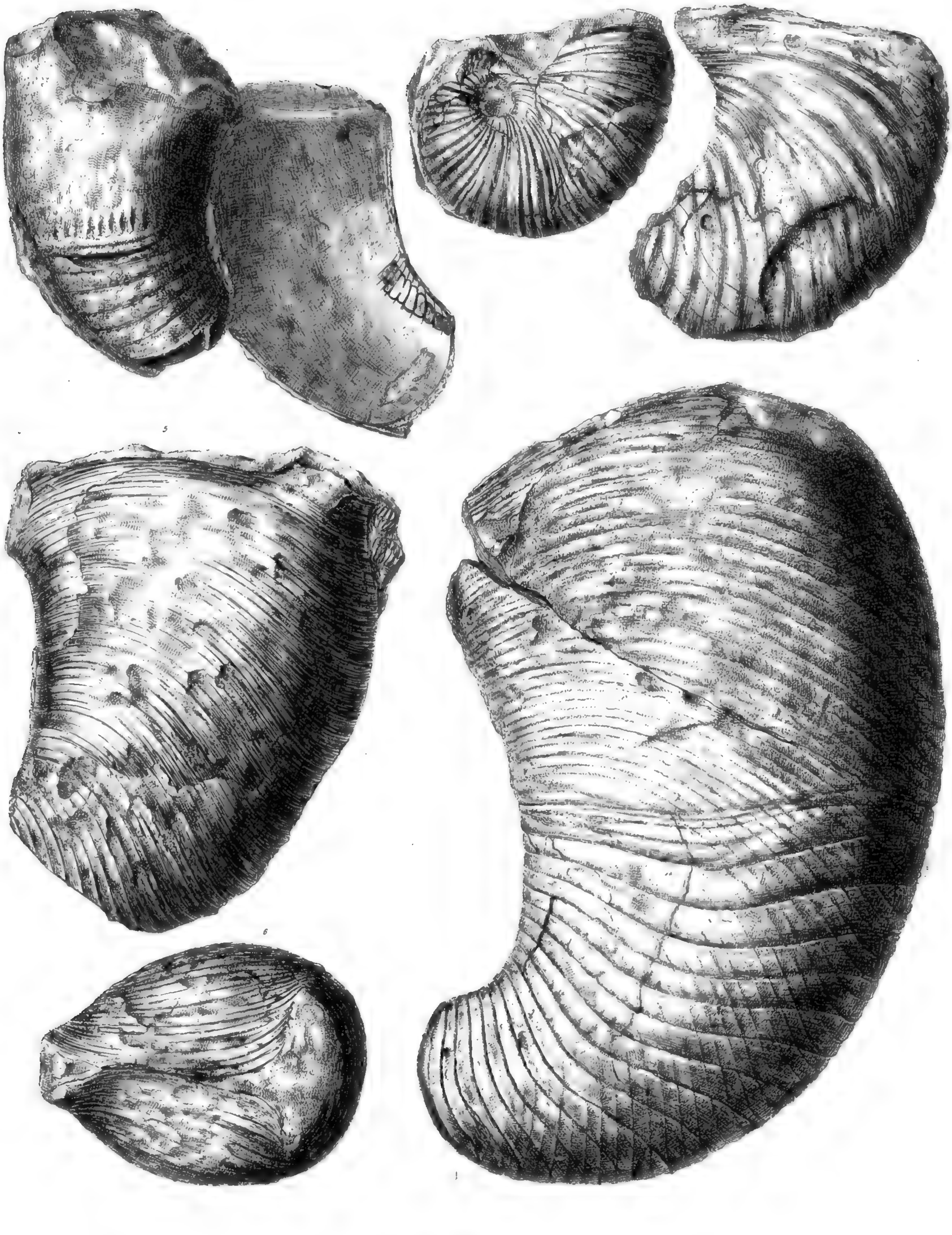
*F. 3. Orthoceras filosum*

*4. ——— virgatum.*

*5. ——— annulatum (M. C.)*

# LOWER LUDLOW ROCK.

(SHELLS.)



1. *Phragmoceras arcuatum*

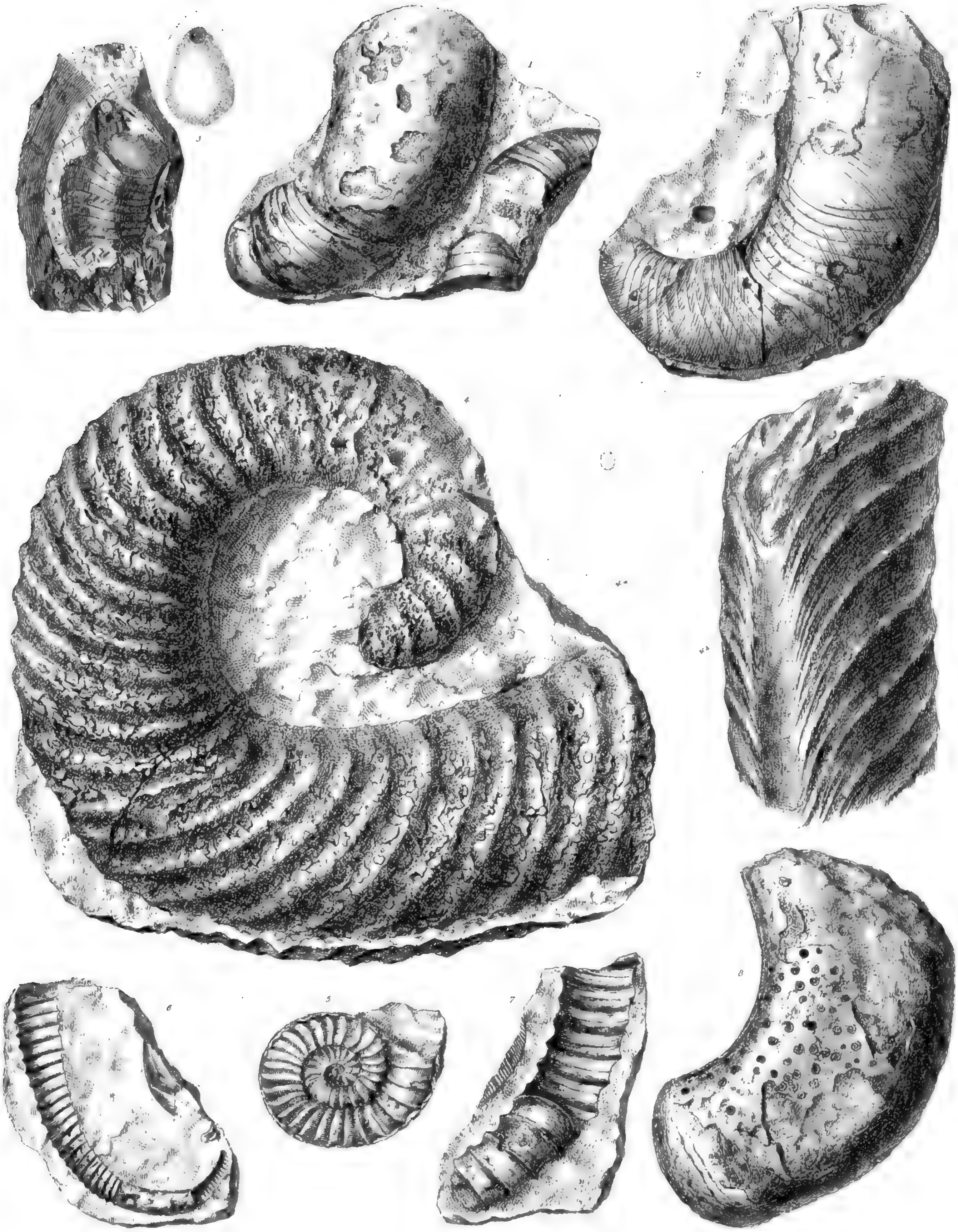
2. 3. – *?nautiloum.*

4. 5. 6. *ventricosum (Orthoceratites ventricosus, Steininger.)*

# LOWER LUDLOW ROCK.

(SHELLS.)

Pl. 11



F. 1. Phragmoceras arcuatum β

2. „ compressum.

3. Lituites tortuosus

F. 5, 7. Lituites articulatus

6, „ ? Ibex

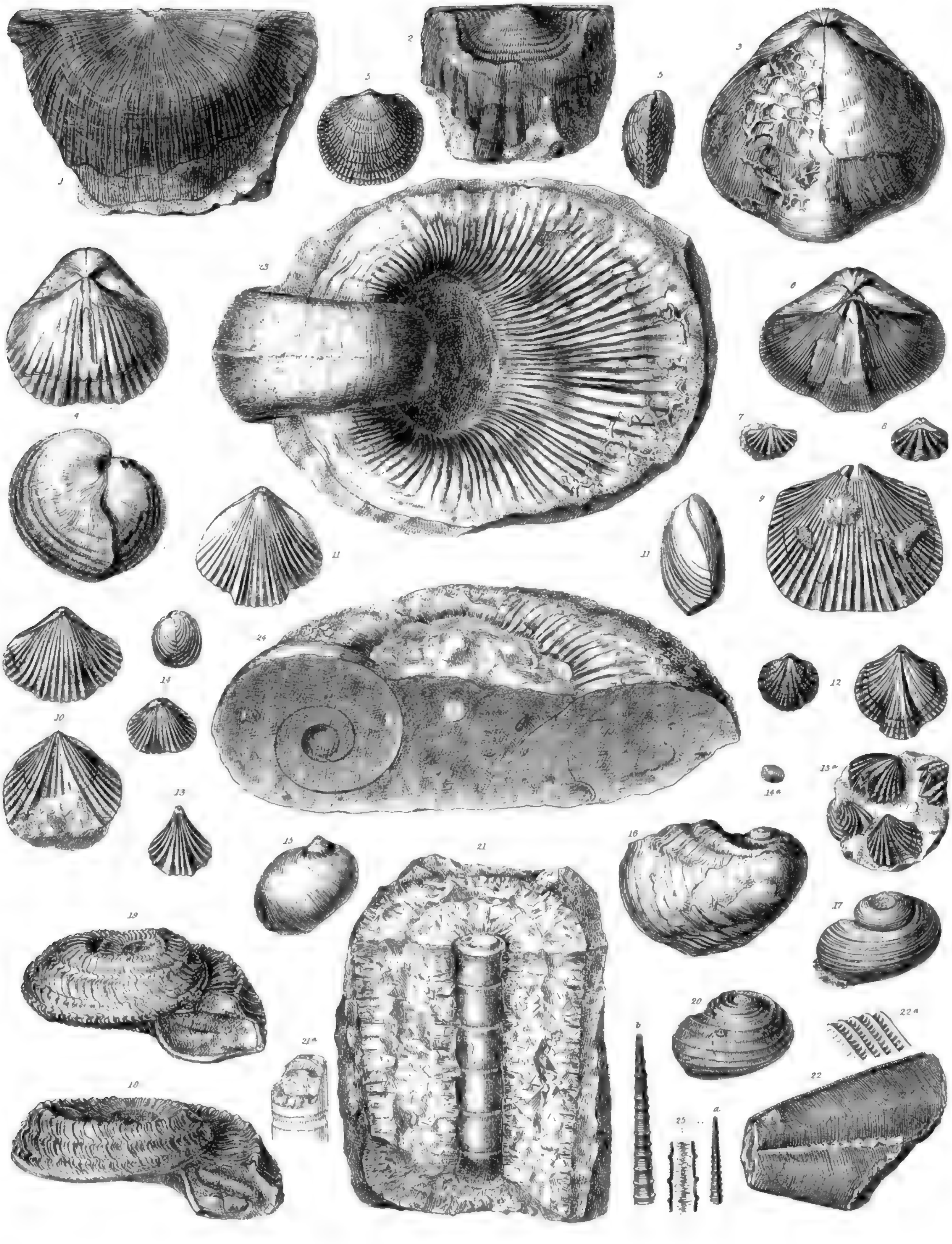
8, „ Biddulphii.

F. 4. Lituites giganteus

WENLOCK LIMESTONE.

(SHELLS.)

Pl. 12.



F 1. Leptæna euglypha. (Dalm.)
2. depressa (M.C.)
3. Atrypa tenuistriata.
4. galeata (Dalm.)
5. aspera (Schloth.)
6. Spirifer radiatus (M.C.)
7. octoplicatus (M.C.)

F 8. Spirifer crispus, (Dalm.)
9. Orthis rustica
10. Terebratula lacunosa, (Schloth.)
11. crispata.
12. imbricata.
13. cuneata (Dalm.)
13a bidentata (His.)

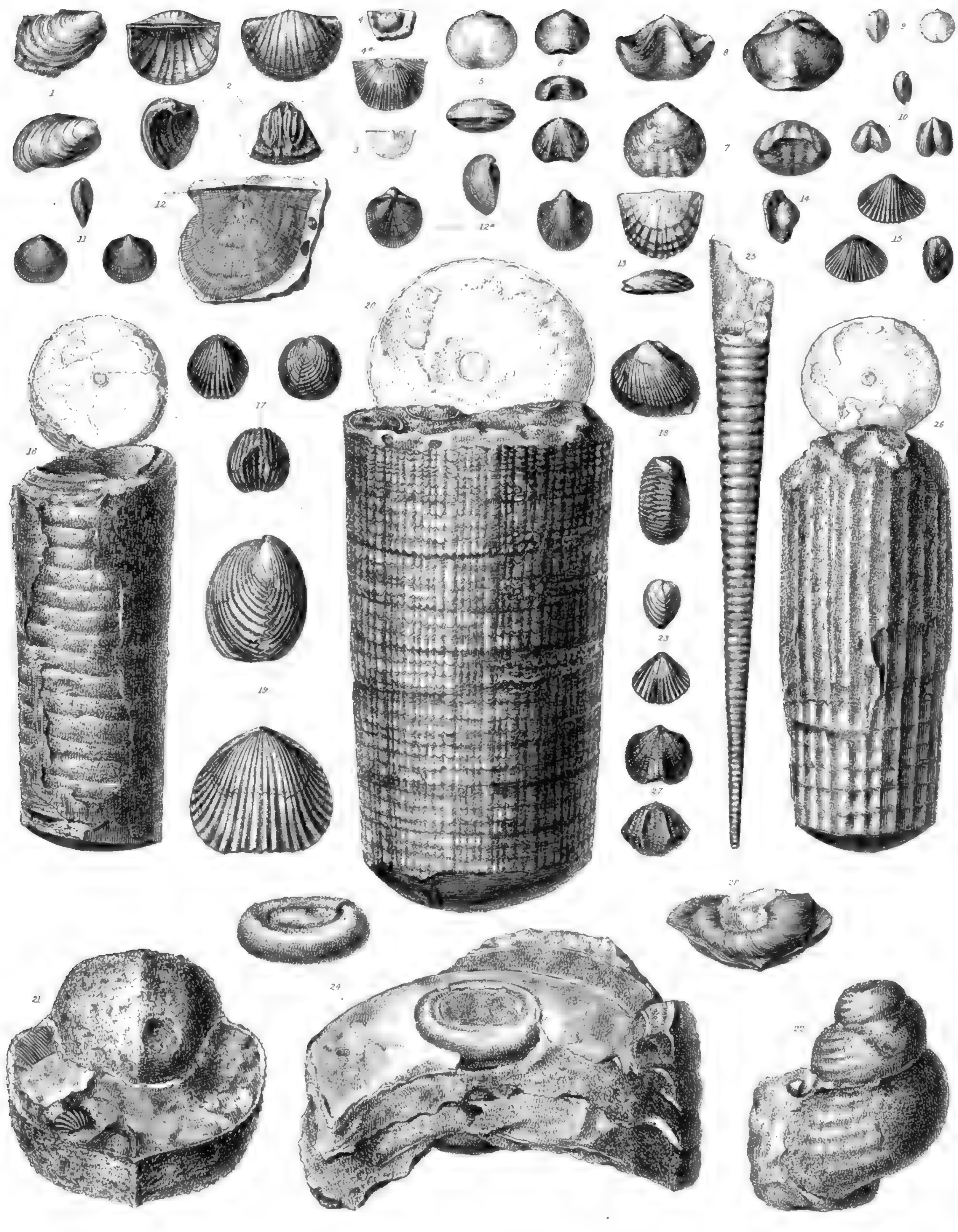
F 14 Terebratula deflexa.
14a Patella? implicata.
15. Nerita spirata (M.C.) var.
16. Haliotis
17. Euomphalus sculptus.
18. discors (M.C.)
19. — rugosus (M.C.)

F. 20. Euomphalus funatus (M.C.)
21. Orthoceras (Ormoceras? Stokes) Brightii
21a Siphuncle of D°
22. Conularia quadrisulcata (Miller)
22a Surface of D° mag^d.
23, 24. Bellerophon dilatatus.
25 Tentaculites ornatus. b. mag^d.

# WENLOCK SHALE.

(SHELLS.)





*E. 1. Modiola antiqua.*
*2. Leptæna transversalis (Dalm.)*
*3. — — lævigata.*
*4. (4ª mag^d.) minima.*
*5. Atrypa compressa.*
*6. — — depressa.*

*E. 7. Atrypa rotunda.*
*8. — — linguifera.*
*9. Spirifer? Pisum.*
*10. — sinuatus (Sowerby.)*
*11. Orthis hybrida.*
*12. — — filosa.*

*E. 12.ª Orthis canalis.*
*13. — antiquata.*
*14. Terebratula læviuscula.*
*15. — — brevirostris.*
*17. — sphærica.*
*18. — — crebricosta.*

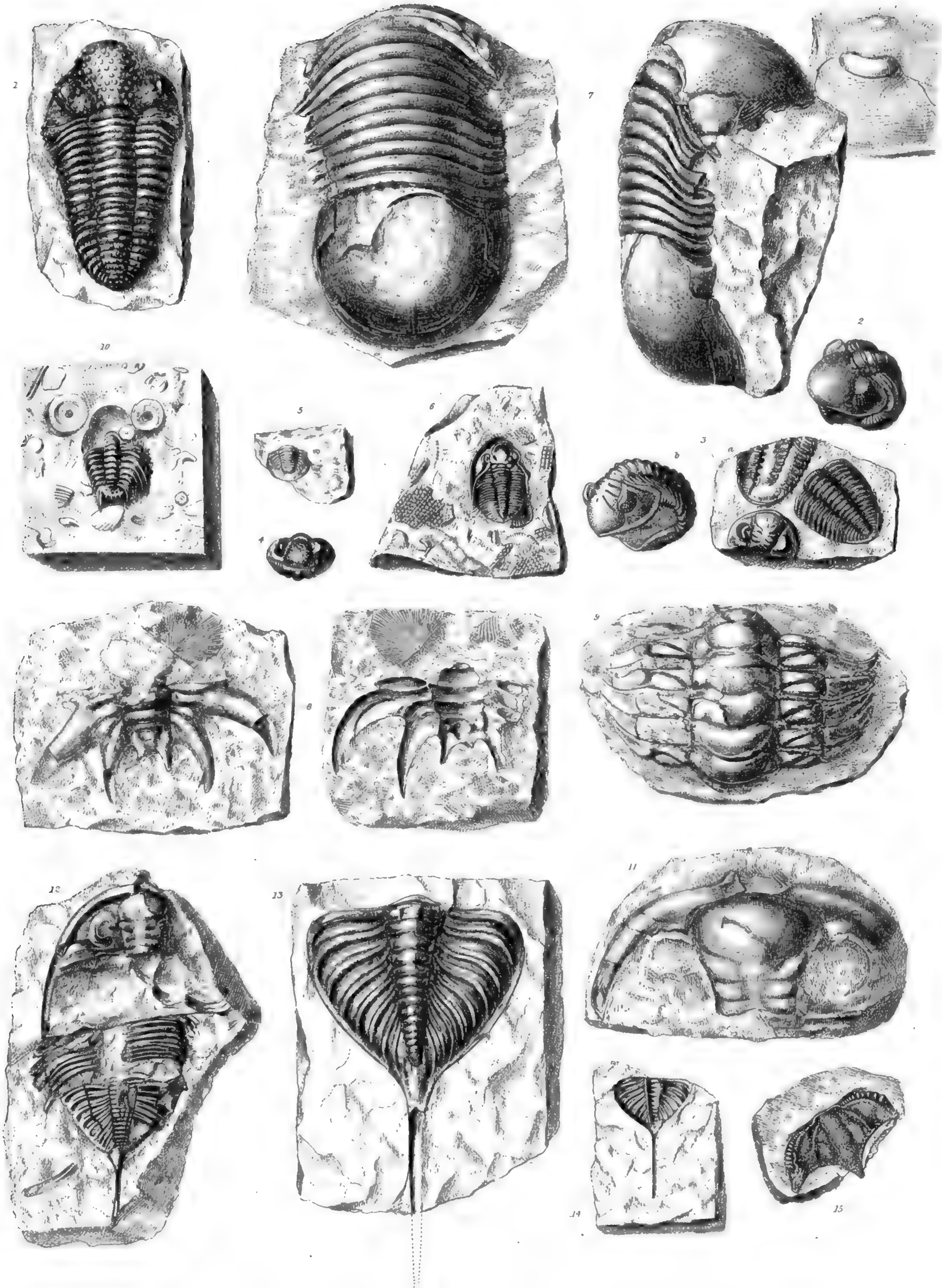
*E. 19. Terebratula Stricklandii.*
*23. — — interplicata.*
*27. — — imbricata, var. abbreviata.*
*16. Orthoceras eccentricum.*
*20. — fimbriatum.*

*F. 24. Orthoceras Nummularius.*
*25. — — attenuatum.*
*26. — canaliculatum.*
*21. Bellerophon Wenlockensis.*
*22. Turbo cirrhosus.*
*28. Euomphalus alatus (Wahl.)*

## WENLOCK LIMESTONE.

(TRILOBITES.)





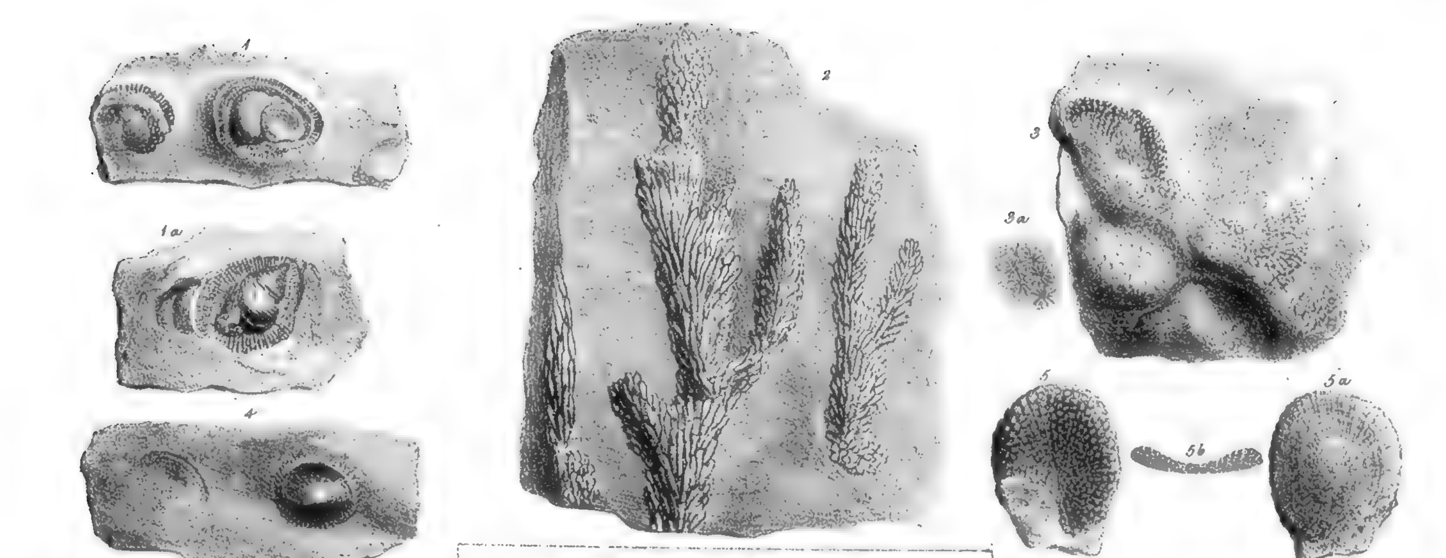
F. 1, Calymene variolaris (Parkᵒⁿ)
2, ——— macrophthalma (Brong.)
3ª & 3ᵇ ——— Downingiæ
4, ——— tuberculata
5, ——— indeterminable

F. 6 Asaphus Stokesii
11-14 ——— longi-caudatus
7 Bumastus Barriensis
8, 9 Paradoxides bimucronatus
10, ——— quadrimucronatus

F. 15, Acidaspis Brightii

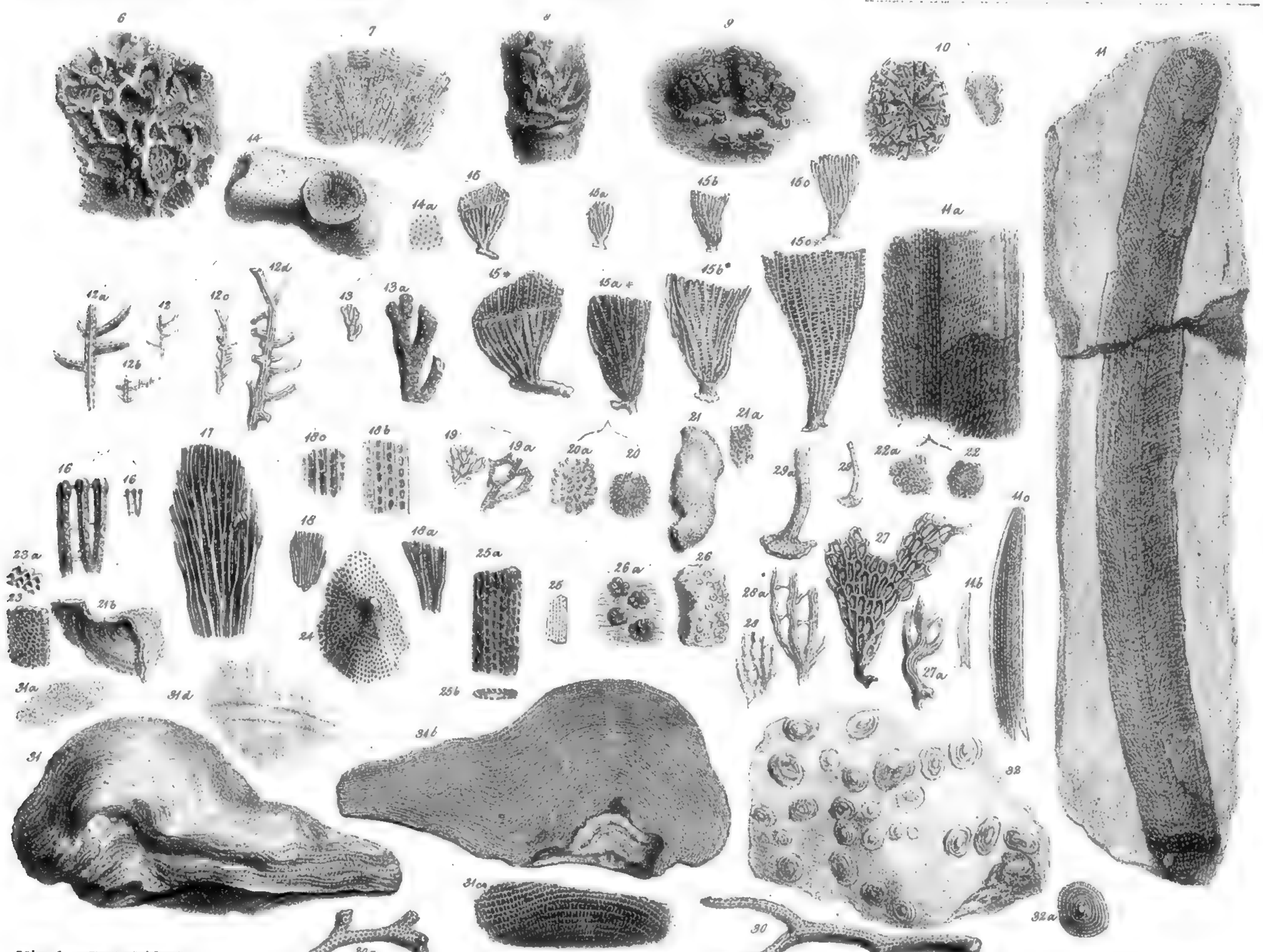
# LUDLOW ROCKS.

CORALS.



# WENLOCK ROCKS.

CORALS



Lithog from Nat by G Scharf

Printed by C. Hullmandel.

1. 1a. Alveolites fibrosa.
2. Favosites polymorpha.
3. 3a Porites expatiata
4. Cyclolites praeacuta.
5. 5a. 5b. C lenticulata.
6. Aulopora serpens.
7. A. consimilis.
8. A. Tubaeformis

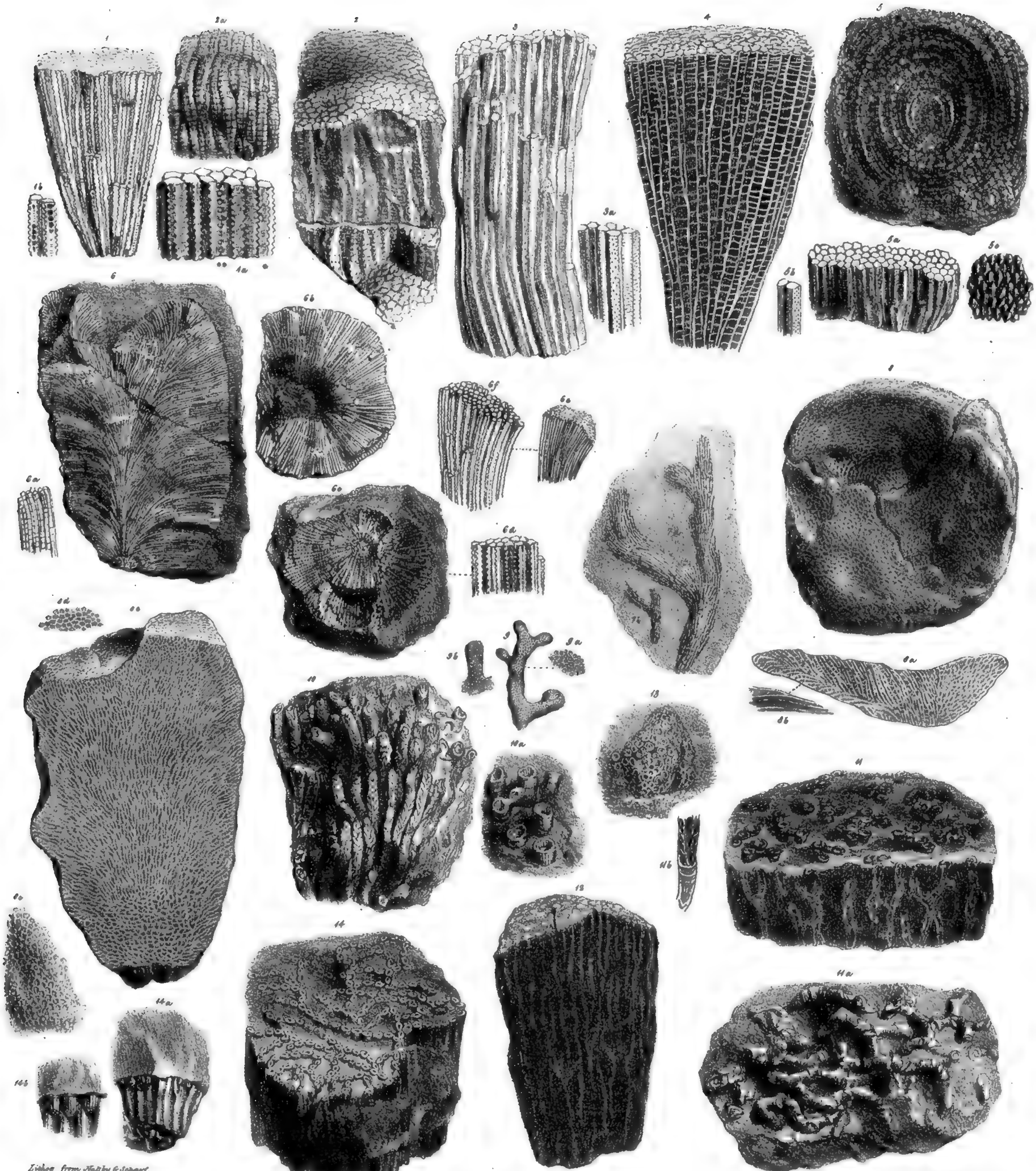
9. Aulopora conglomerata.
10. Escharina ? angularis.
11. 11a to 11c Ptilodictya lanceolata.
12. 12a to 12d. Glauconome disticha.
13. 13 a. Hornera crassa.
14. 14 a Heteropora crassa.
15. 15a to 15c 18. 18a to 18c. Fenestella prisca.
16. 16 a F antiqua.

17. Fenestella Milleri.
19. 19a F. reticulata
20. 20 a Berenicea irregularis
21. 21a 21 b. Discopora antiqua.
22. 22 a. D? favosa
23. 23a D squamata
24. Retepora infundibulum
25. 25a 25b Eschara scapellum.

26. 26 a. Blumenbachium globosum ?
27. 27 a Gorgonia assimilis
28. 28 a. Gorgonia ?
29. 29 a. Cerigopora granulosa
30. 30 a. Millepora repens.
31. 31 a to 31 d. Stromatopora concentrica.
32. 32 a. S nummulitisimilis.

## WENLOCK ROCKS.

(CORALS.)

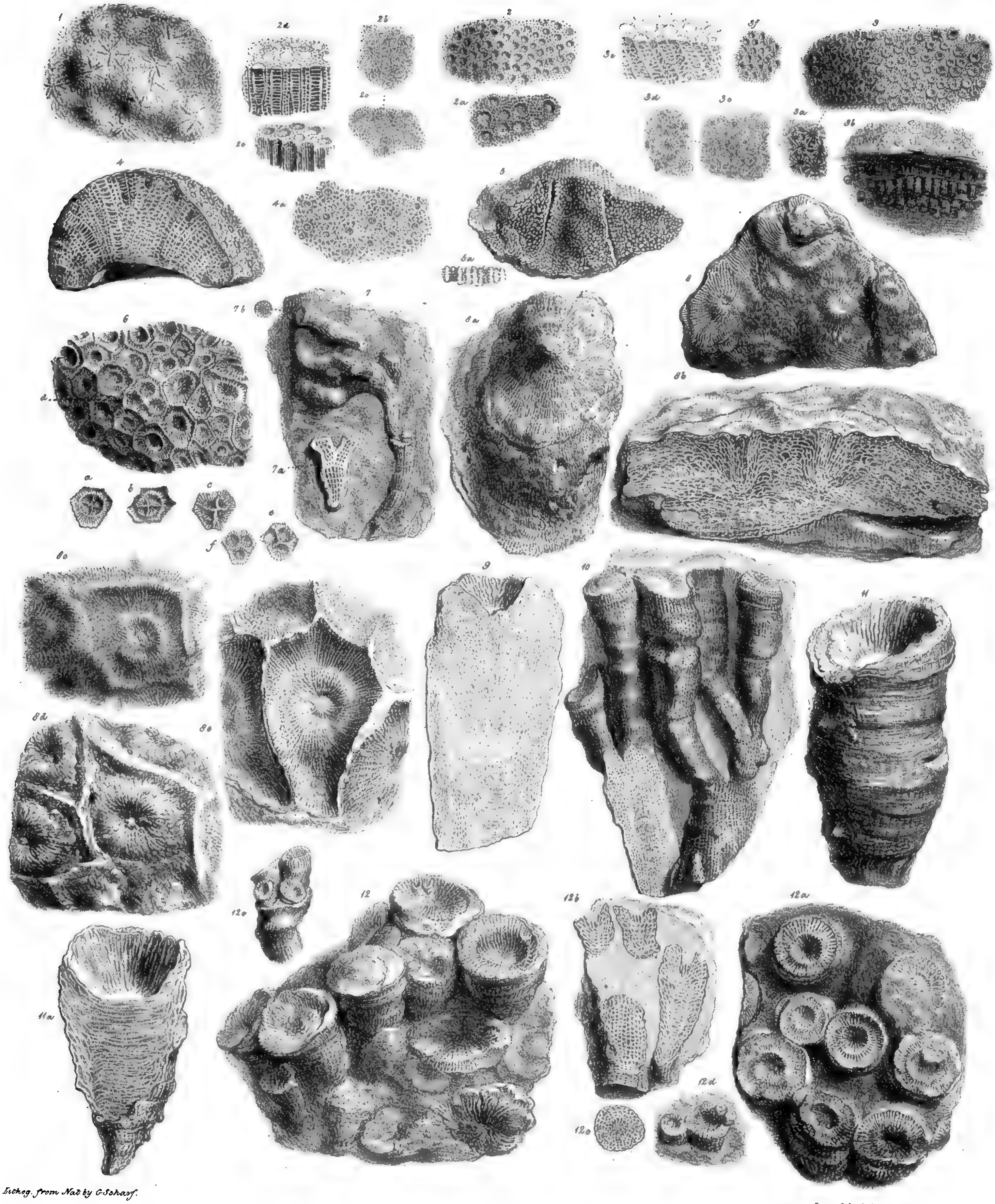


Lithog. from Nat. by G. Scharf. | Printed by C. Hullmandel.

1. 1 a. 1 b. 2. 2 a. *Favosites alveolaris.*
3. 3 a. 4. *Favosites Gothlandica.*
5. 5 a. to 5 c. *Favosites multipora.*
6. 6 a. to 6 f. *Favosites fibrosa.*
7. 7 a. *Favosites fibrosa.*
8. 8 a. to 8 e. *Favosites spongites.*
9. 9 a. 9 b. *Favosites spongites.*
10. 10 a. *Syringopora reticulata.*
11. 11 a. 11 b. *Syringopora bifurcata.*
12. *Syringopora filiformis?*
13. *Syringopora cæspitosa.*
14. 14 a. 14 b. *Catenipora escaroides.*

# WENLOCK ROCKS.

(CORALS)



Lithog. from Nat. by G. Scharf.

Printed by C. Hullmandel

1. Porites discoidea.
2. 2a. to 2e. Porites pyriformis.
3. 3a to 3f. Porites tubulata.
4. 4a. Porites petalliformis
5. 5a Monticularia conferta
6. 6a to 6f Astrea ananas
7. 7a. 7b Caryophyllia flexuosa.
8. 8a to 8e. Acervularia Baltica.
9. Cyathophyllum angustum.
10. Cyathophyllum cæspitosum.
11. 11a. Cyathophyllum turbinatum
12. 12a to 12e Cyathophyllum dianthus

WENLOCK ROCKS. 1 to 5 7 to 11. Pl. 16. Fig.

CARADOC SANDSTONE 6. LLANDEILO FLAGS 12

(CORALS)

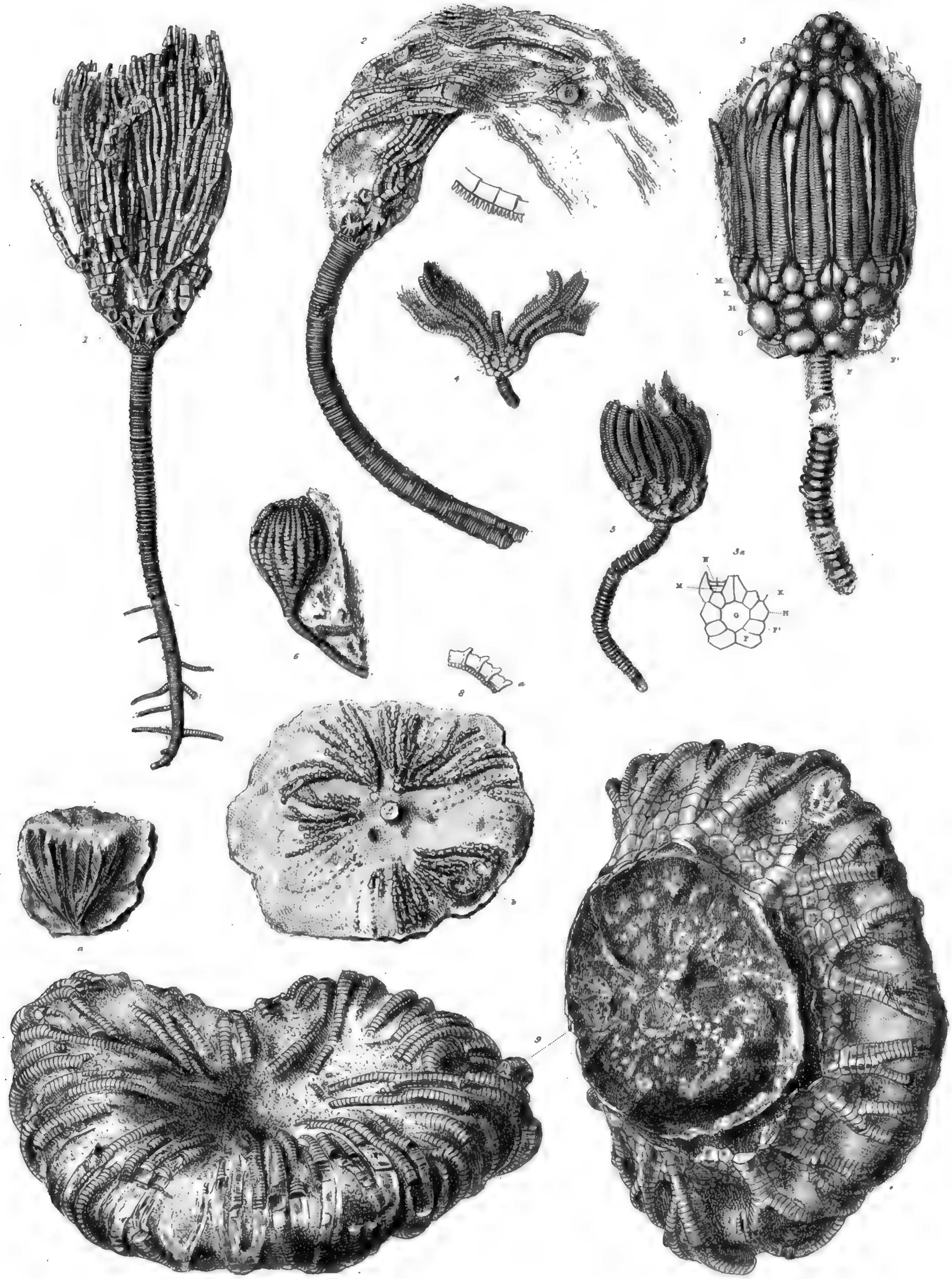
Lithog. from Nat. by G. Scharf

Printed by C. Hullmandel

1 1 a. 2 Cystiphyllum Siluriense.
3. 3a. 3b. Cystiphyllum cylindricum.
4 4a. to 4c. Strombodes plicatum.
5 5a. Turbinolopsis bina
6 6a Turbinolopsis.
7. 7a. 7b Limaria clathrata.
8 8a. Limaria fruticosa.
9 9a. 9b. Cladocora sulcata.
10. 10 a. to 10 d. Verticillipora ? abnormis.
11 11a 11b. Cnemidium tenue.
12 12a to 12c. Porites ? inordinata.

# WENLOCK LIMESTONE.

(CRINOIDEA.)



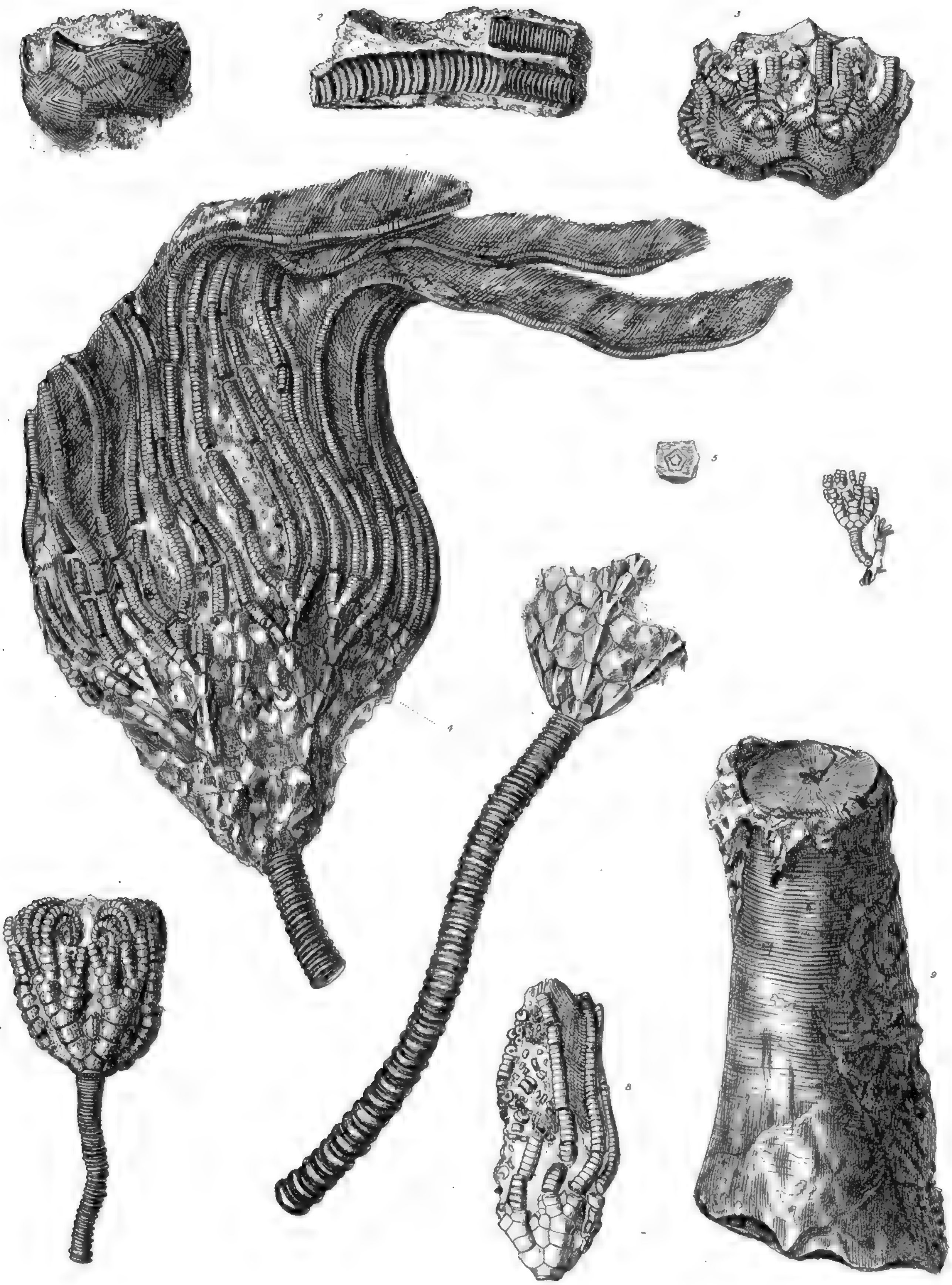

*F. 1. Cyathocrinites goniodactylus.*
*2. ———— capillaris.*
*6. ———— pyriformis.*

*F. 3. Hypanthocrinites decorus.*
*4. Dimerocrinites decadactylus.*
*5. ———— icosidactylus.*

*F. 7. Actinocrinites ? retiarius.*
*8. ———— ? arthritious.*
*9. ———— ? expansus.*

## WENLOCK LIMESTONE, &c.

(CRINOIDEA)



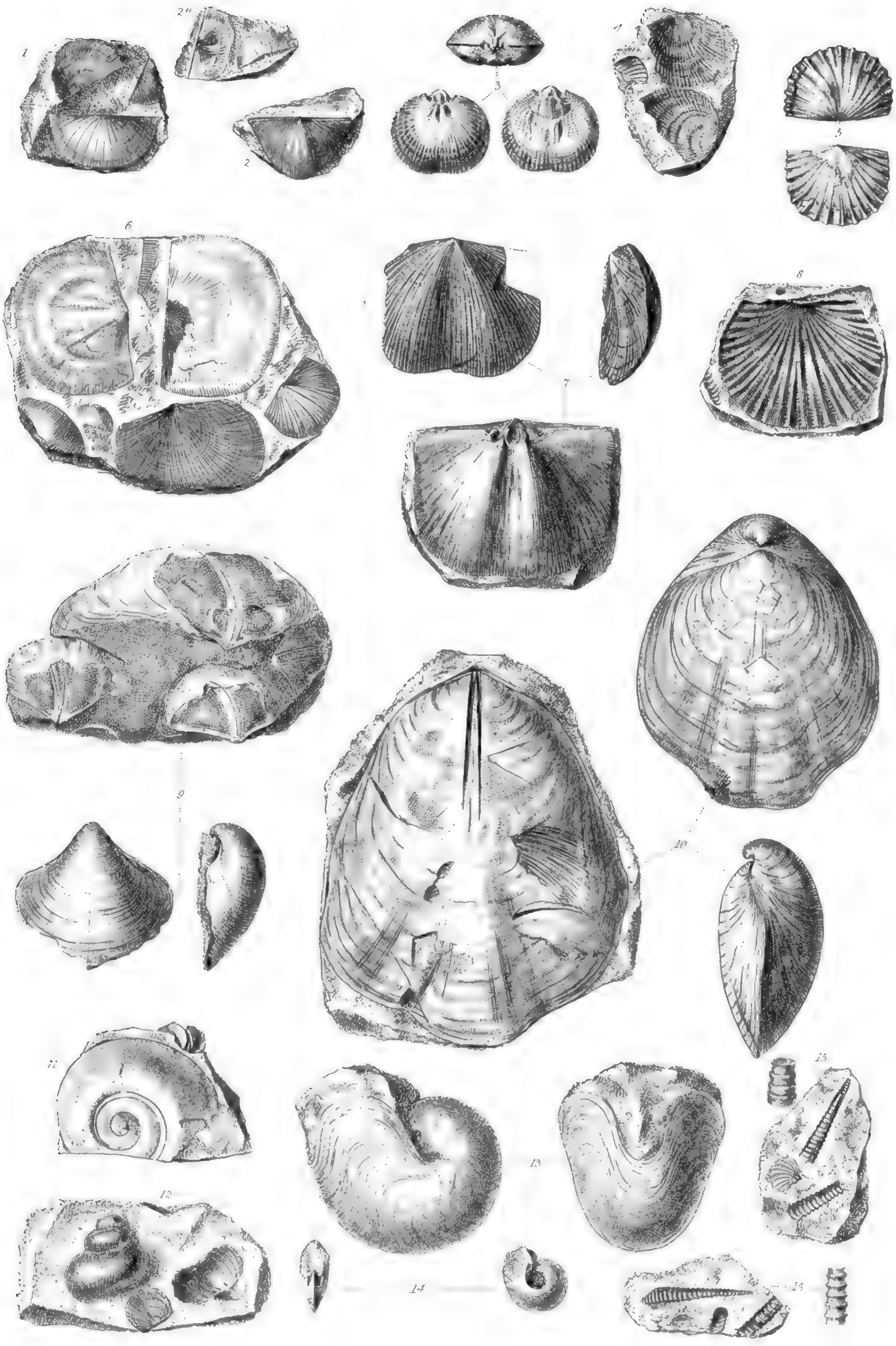

F 1. *Cyathocrinites rugosus* (Mill.)
7. — — — *tuberculatus* (Mill.)
6. — — D° junior
3. *Marsupiocrinites cœlatus*

F 4. *Actinocrinites moniliformis* (Mill.)
8. — — *simplex*
5. *Rhodocrinites quinquangularis* (Mill.)
2, 9. *Columns of indeterminable Crinoidea*

# CARADOC SANDSTONE.

(SHELLS)





F. 1, 2ª Leptæna sericea
2. — — — var.
3, 4 Atrypa orbicularis
5 Orthis callactis B. (Daum.)

F. 6, Orthis alternata
7, — — bilobata
8, — Flabellulum, B
9, Pentamerus lævis (M. C.)

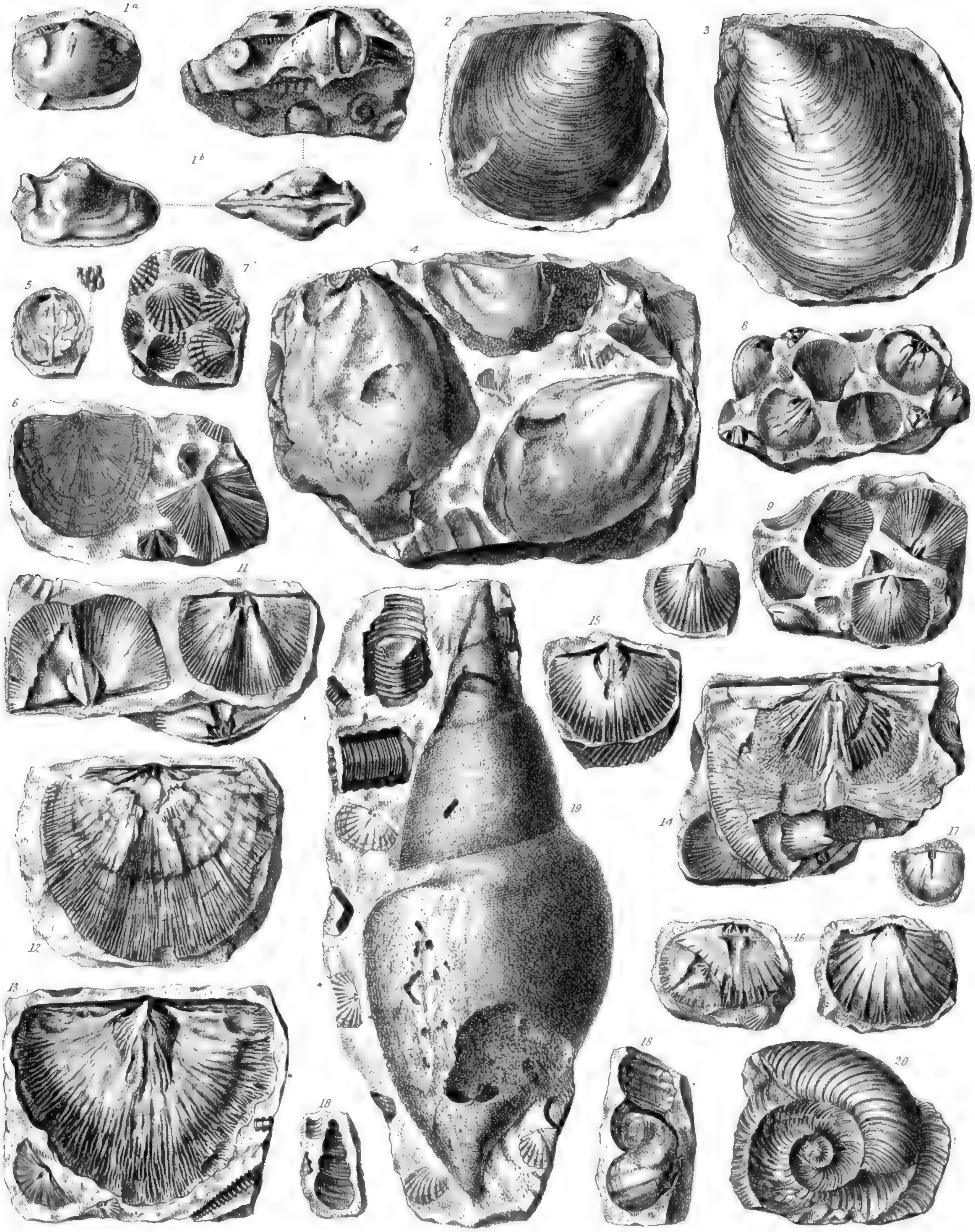
F. 10, Pentamerus oblongus
11, Trochus lenticularis
12, Littorina striatella
13, Bellerophon bilobatus

F. 14, Bellerophon acutus
15, Tentaculites scalaris (Schloth.
16. — annulatus Schloth.

## CARADOC SANDSTONE.

(SHELLS)





F.1a 1b Arca Eastnori
2. Avicula orbicularis.
3 var.
4. — obliqua

F.5. Orbicula punctata (granulata in Desc.)
6. Leptæna complanata
7. Atrypa hemisphærica
8. Orthis canalis

F.9.10 Orthis testudinaria ? (Dalm.)
11. Vespertilio
12.13. grandis
14 expansa

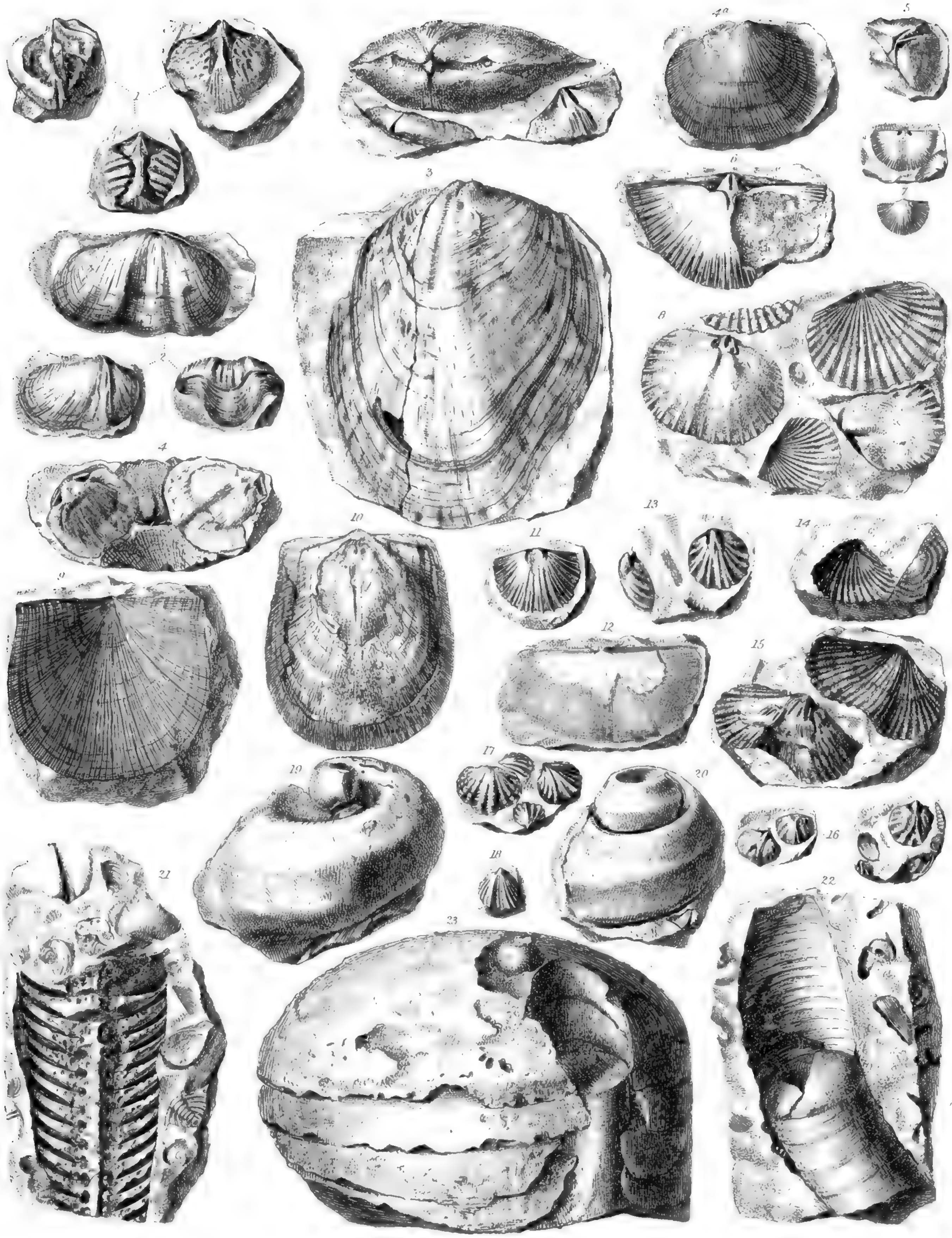
F.19. Bucanum ? fusiforme
20. Lituites Cornu-Arietis, a

F.15. Orthis virgata
16. Actoniæ
17. triangularis
18. Turritella cancellata

N.B. Although the words "Caradoc Sandstone" are prefixed to Pl. 21, and "Llandeilo Flags" to Pl. 22, the first of these plates contains forms (f. 1 and 2) which occur in the "Llandeilo Flags," while there are shells in the second (f. $2^a$, $2^b$, 11, and 12) which are referrible to the "Caradoc Sandstone." See Tabular List and Description.

# CARADOC SANDSTONE.

(SHELLS)



F. 1. Atrypa crassa
2. — undata.
3. — Lens
4. — ? plana
4a. — polygramma.
5. Spirifer radiatus (M.C.) var.

F. 6. Spirifer ? plicatus
12. — ? lævis.
7. Orthis semicircularis.
8. — Flabellulum α.
9. — Pecten ? (Dalm.).
10. — anomala ? (Schloth.)

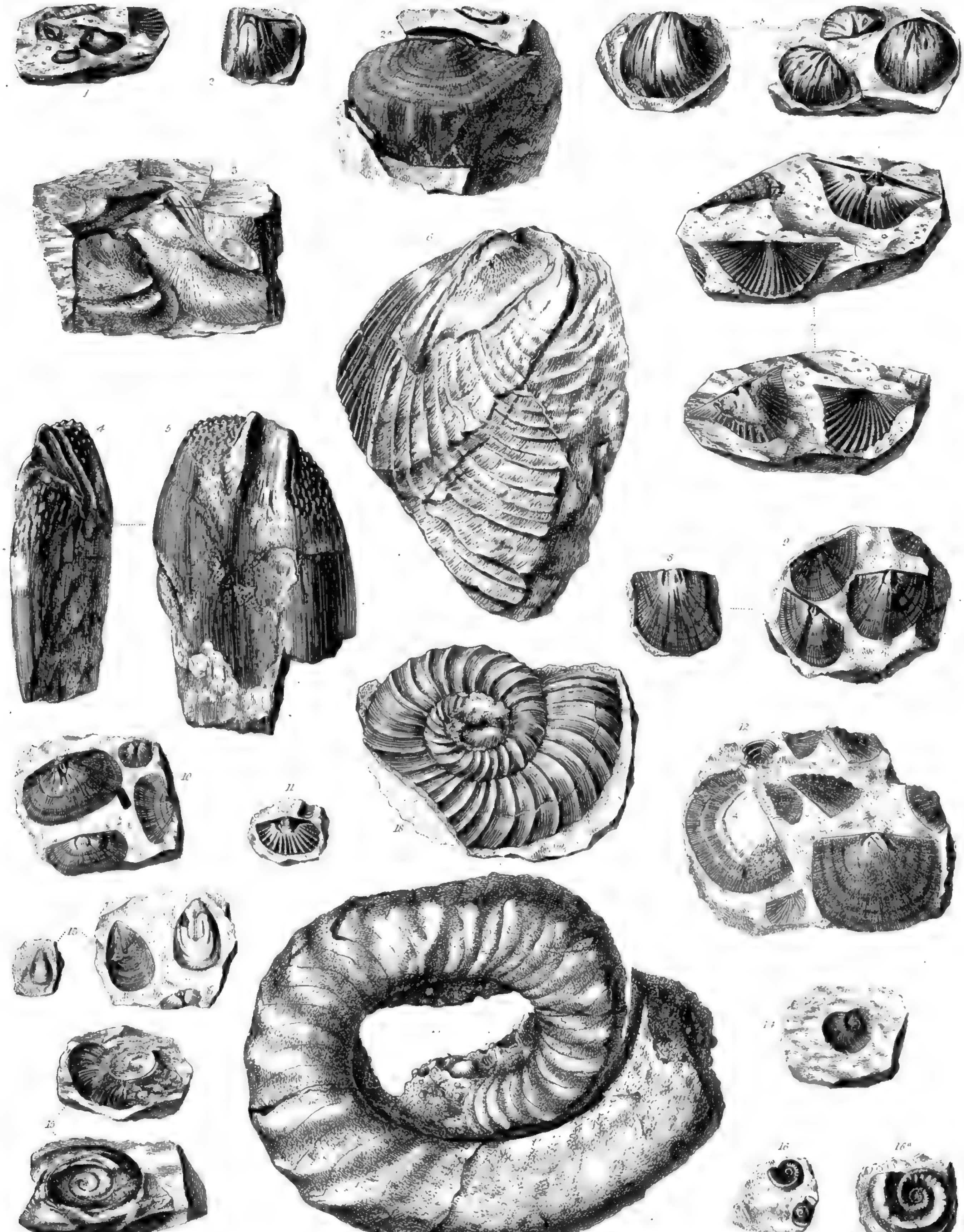
F. 11. Orthis costata.
13. Terebratula Unguis
14. — neglecta.
15. — tripartita
16. — furcata.
17. — decemplicata

F. 18. Terebratula pusilla.
19. Turbo? Pryceæ
20. Pleurotomaria angulata.
21. Orthoceras conicum
22. — approximatum
23. — bisiphonatum

# LLANDEILO FLAGS.



(SHELLS)



F.1. Nucula ? lævis
2. Leptæna duplicata
2ª. — tenuistriata
2ᵇ. Atrypa globosa
3. Atrypa (internal cast)

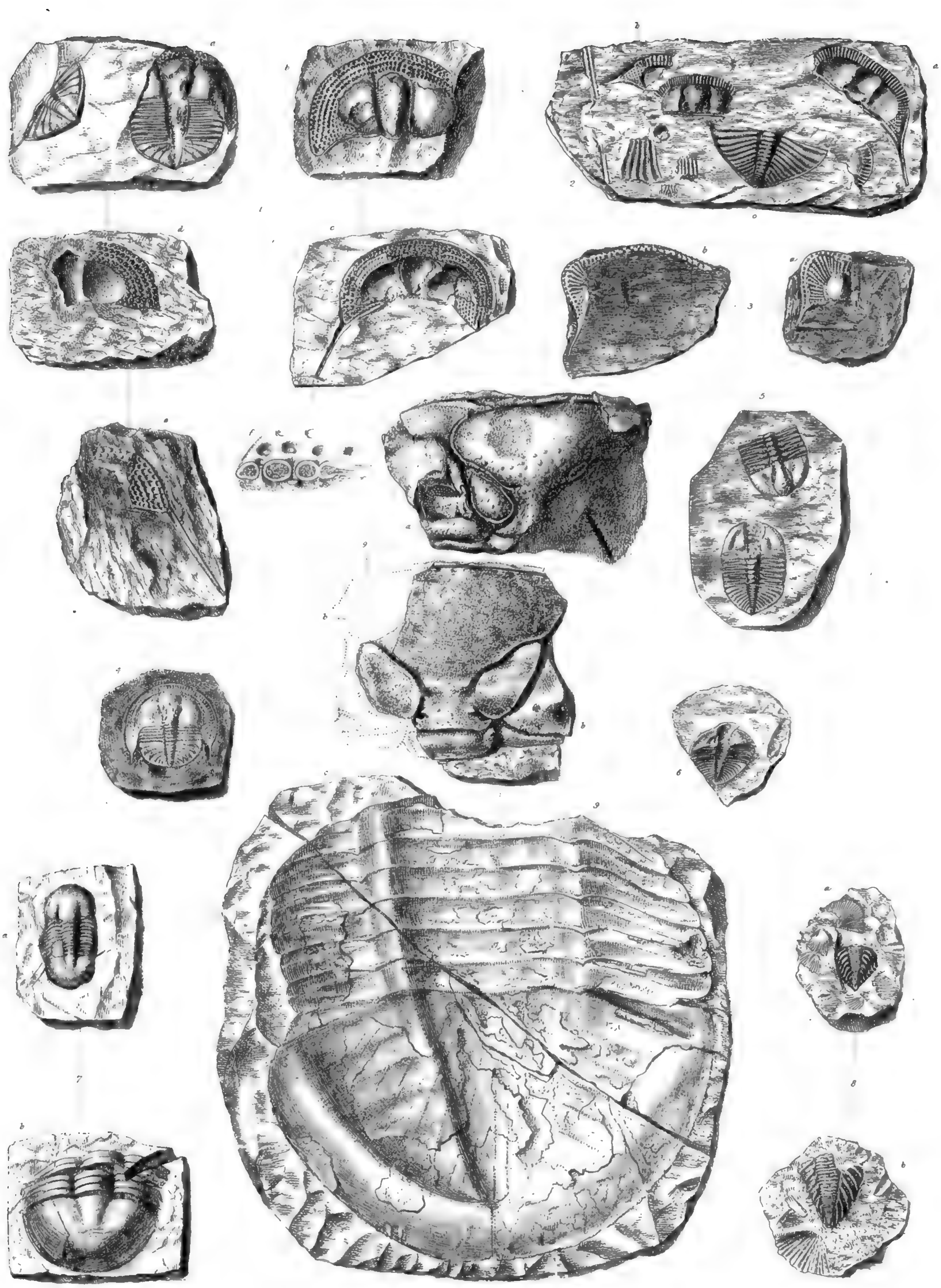
F.4, 5. Atrypa (internal cast)
6. Spirifer ? liratus
7. — ? alatus
8, 9. Orthis protensa.
10. — — lata

F.11. Orthis radians
12. — — compressa.
13. Lingula attenuata
14. Euomphalus tenuistriatus
15. — — perturbatus

F.16. Euomphalus corndensis.
16ª. The same mag.ᵈ
17. Nautilus (Clymene? Münster) undosus
18. Lituites Cornu-arietis. β.

# CARADOC SANDSTONE.

(TRILOBITES.)



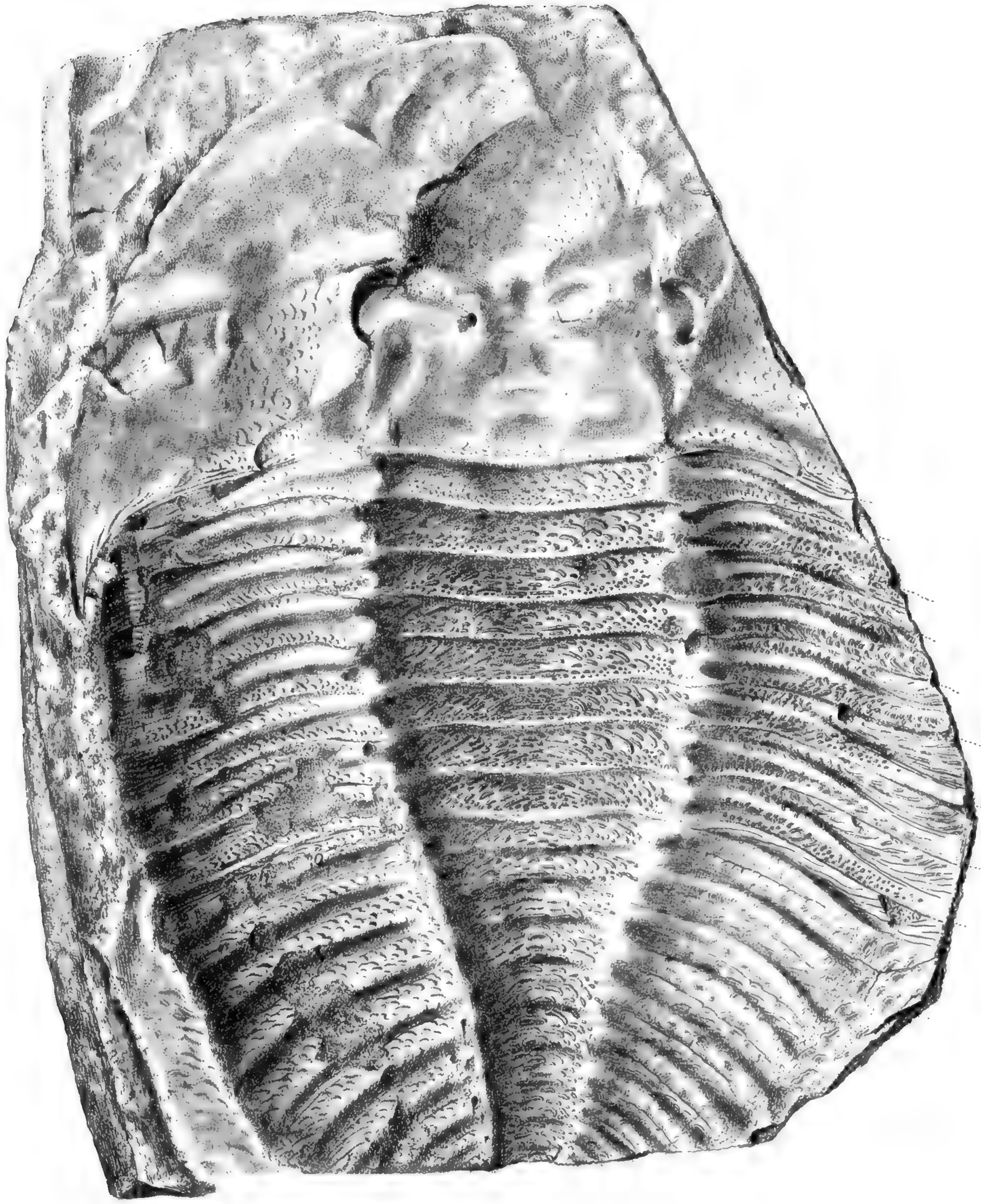
F. 1, Trinucleus Caractaci.
2, ——— fimbriatus.
3, ——— radiatus.

F. 4, Trinucleus Lloydii.
5, ——— nudus
6. ——— Asaphoides.

F. 7, Illænus perovalis
8, Calymene punctata, (Wahl)
9. Asaphus Powisii

LLANDEILO FLAGS.

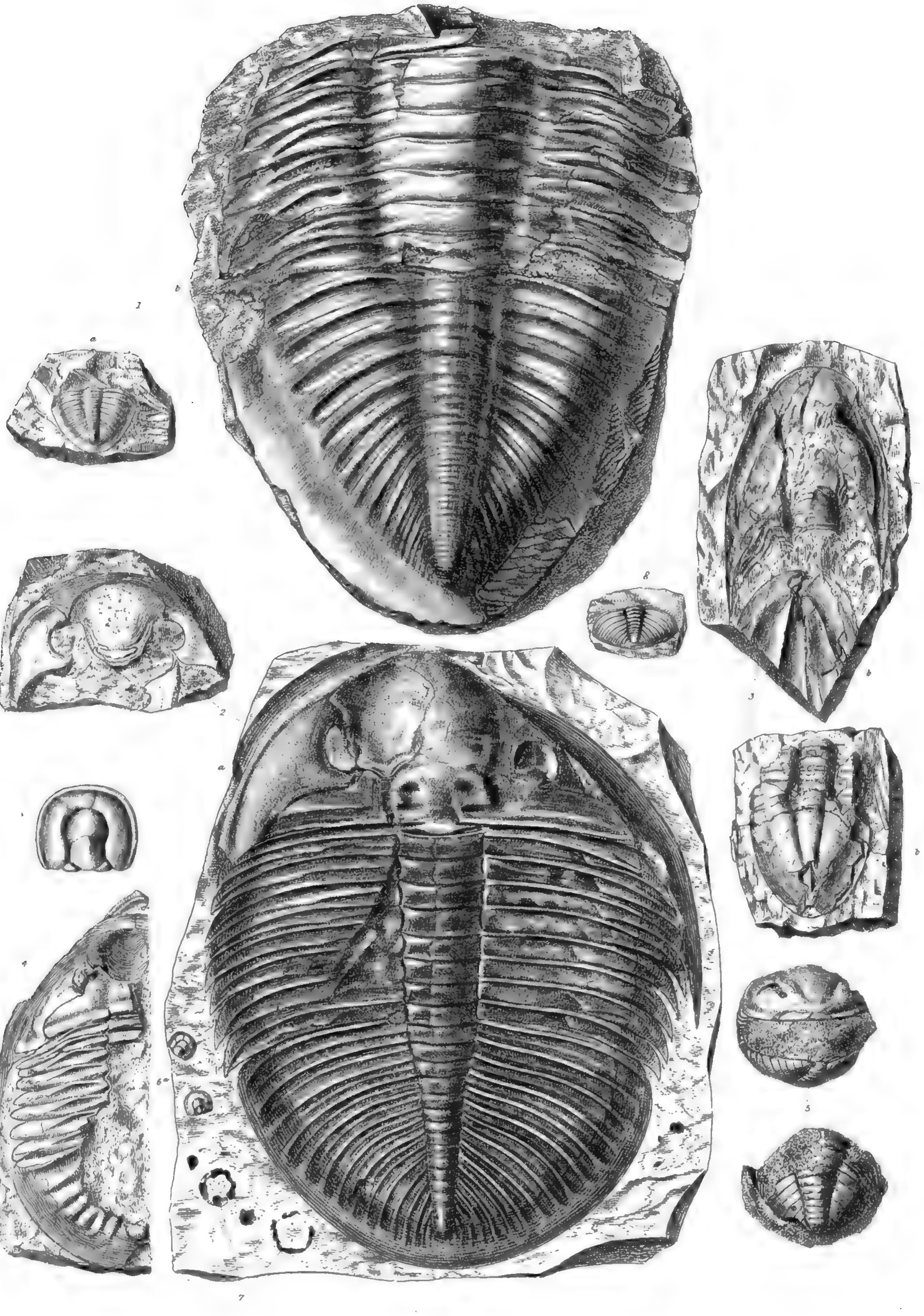
(TRILOBITES.)



*Asaphus Tyrannus, (var. ornata.)*

# LLANDEILO FLAGS.

(TRILOBITES.)



F. 1. Asaphus Tyrannus — F. 5. Asaphus Vulcani.

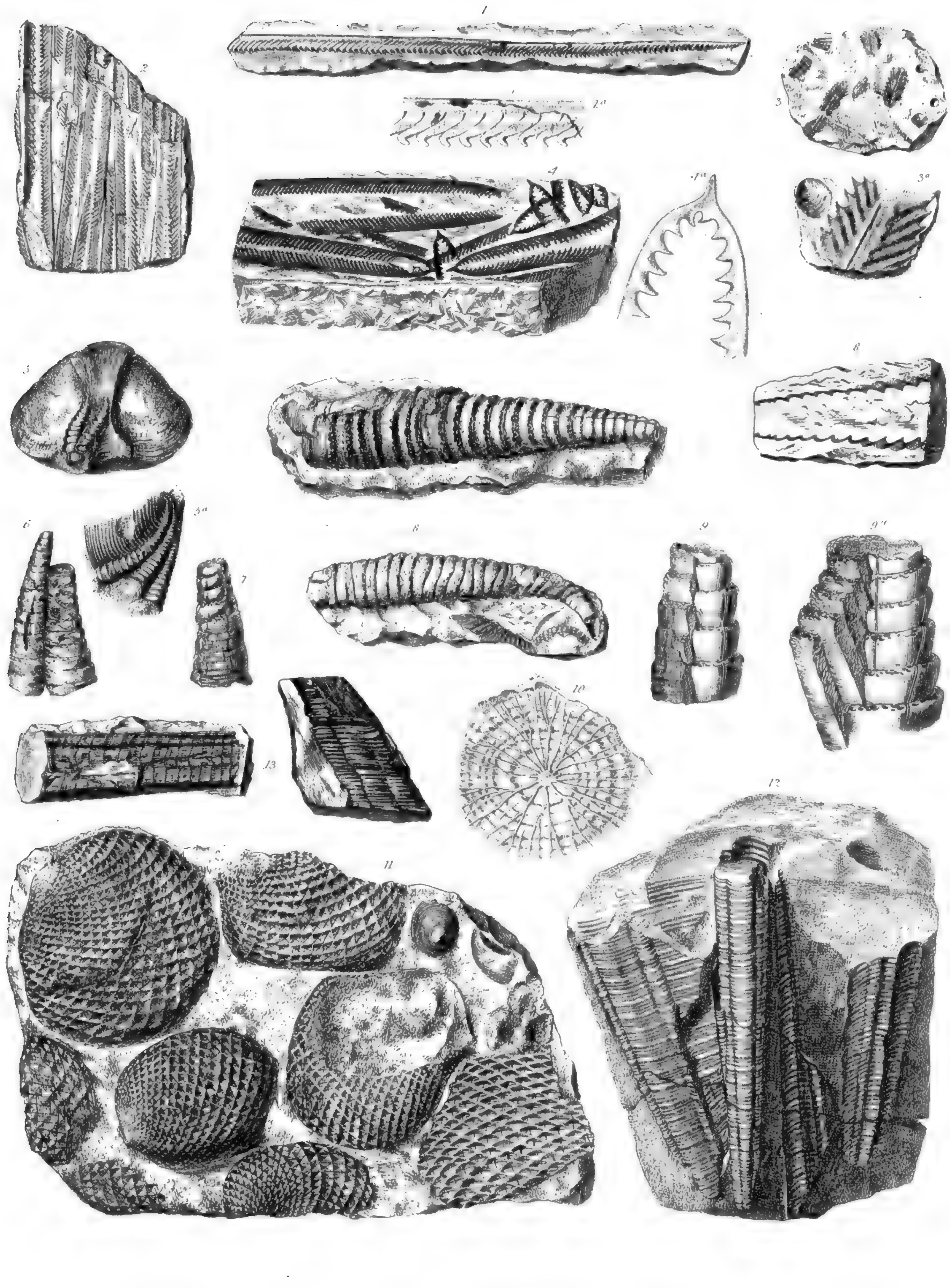
2. — — Buchii (Brong.) — 3. Ogygia Murchisoniæ.

7. — — Corndensis. — 6. Agnostus pisiformis.? (Brong.)

8. — — duplicatus — 7. Imperfect Crinoidal casts

# MISCELLANEOUS.

Pl. 26.

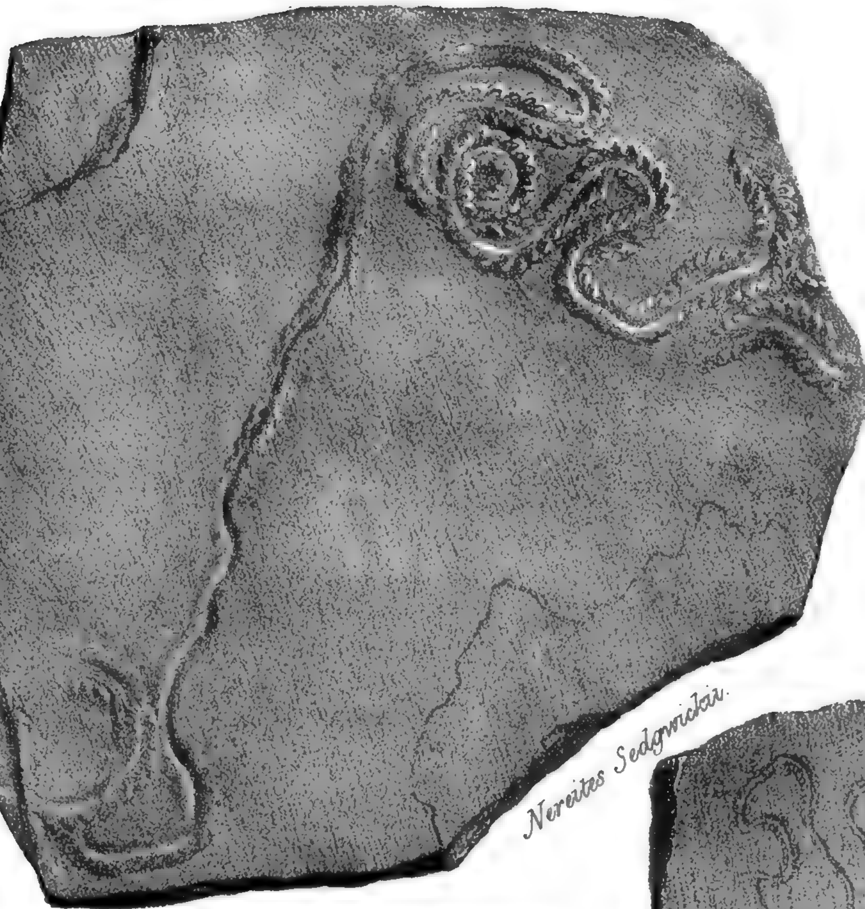


F. 1. 2. *Graptolithus Ludensis*
3. *foliaceus*
4. *Murchisoni Beck*

F. 5. 8. *Cornulites serpularius (Schloth.) nat. size*
9. *Portions of d.° mag.d*
10. *Spongarium Edwardsii.*

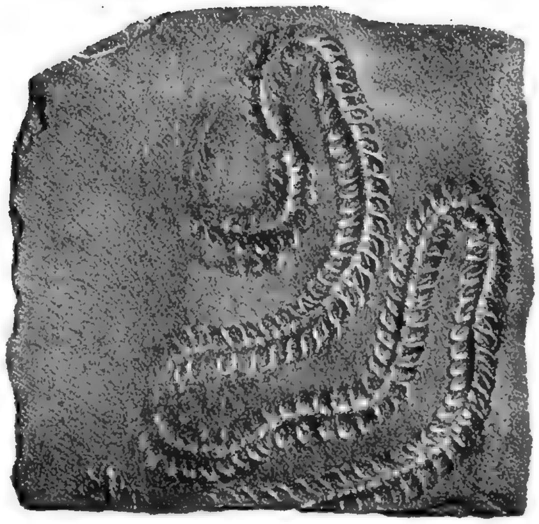
F. 11. *Ischadites Kœnigii*
12. *Cophinus dubius*
13. *Polymeres Demetarum*

2



Nereites Sedgwickii.

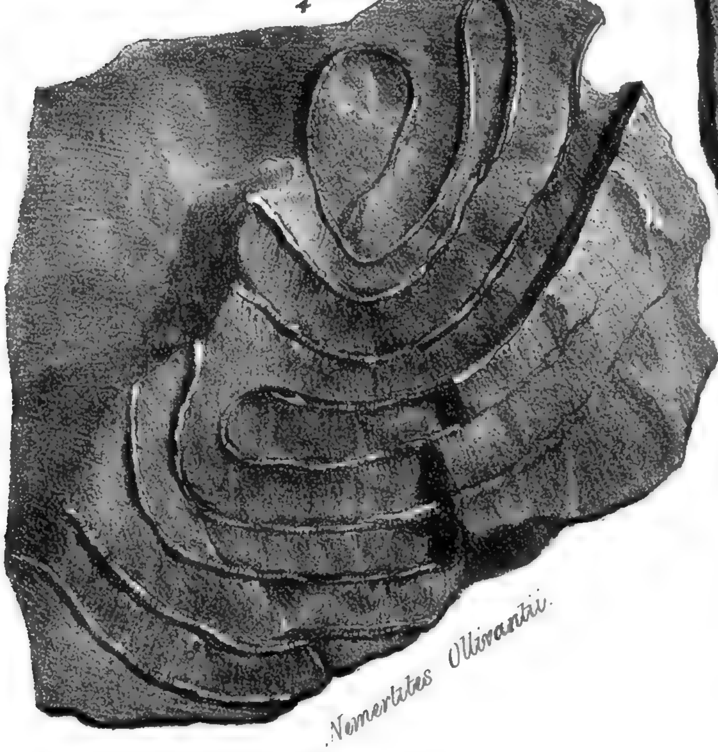
1



Nereites Cambrensis

3

4



Nemertites Ollivantii.

Myrianites Macleayii.

G. Scharf del. et lithog.

Printed by C. Hullmandel.